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INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

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WEST BENGAL POWER & WATER RESOURCES DEVELOPMENT
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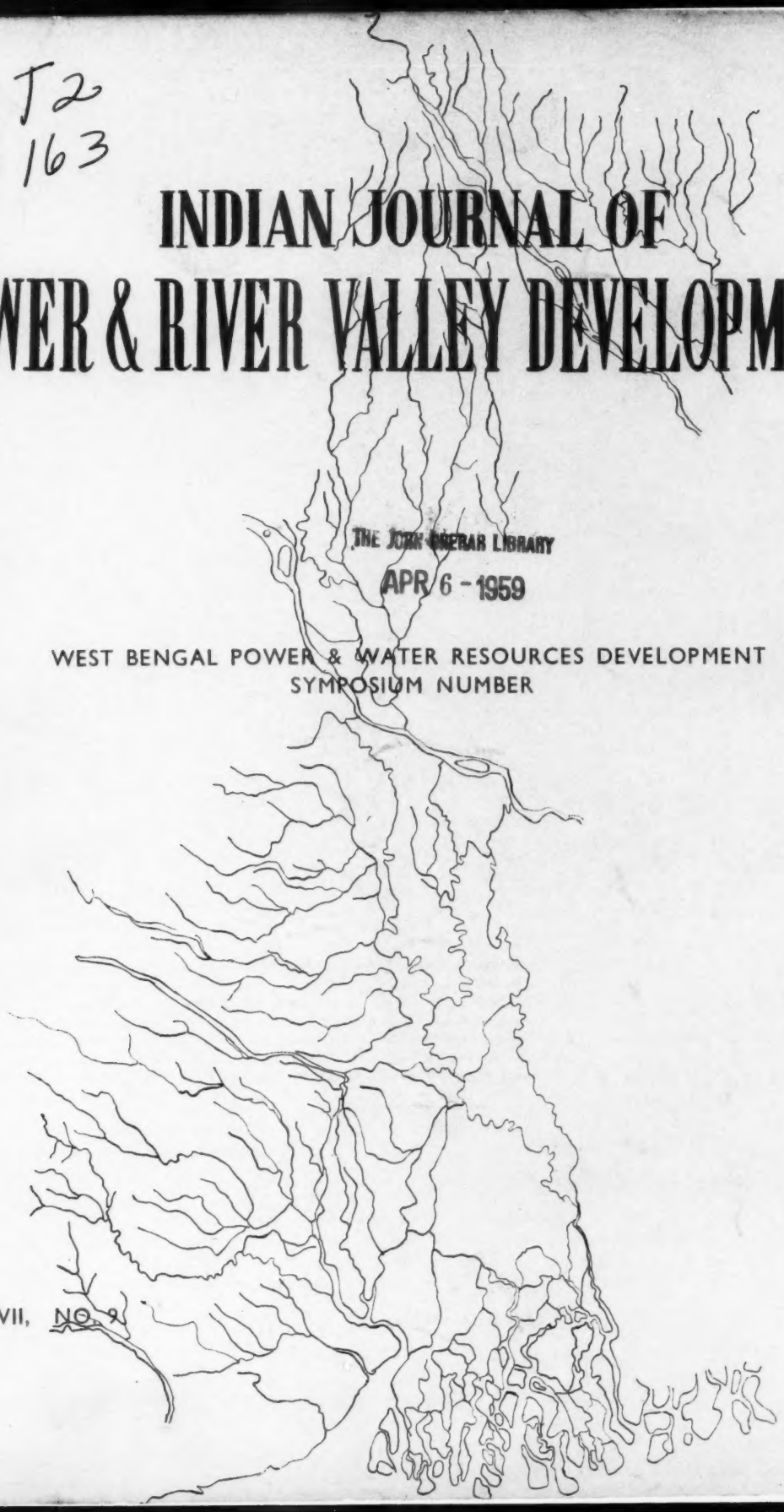

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a basic factor of life

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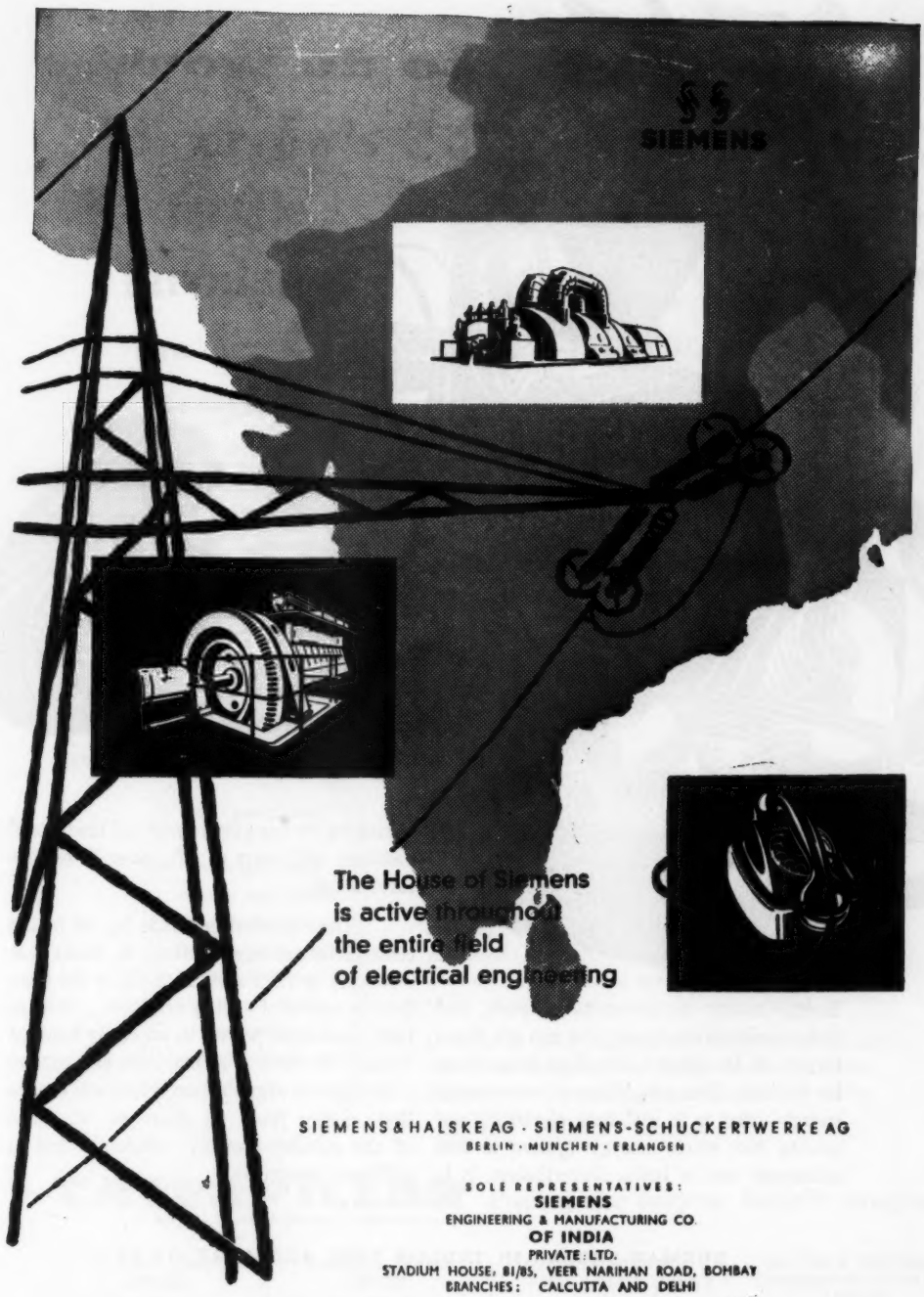

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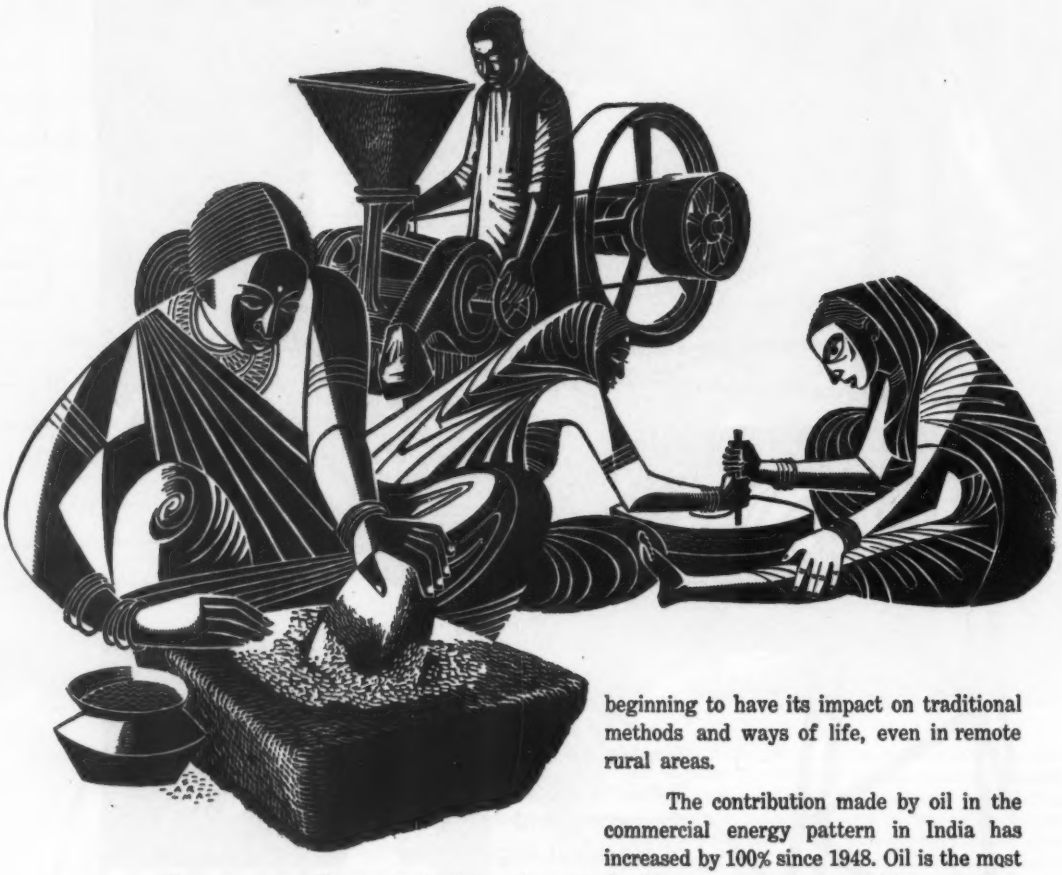

Energy means the power to do work, and India needs all the energy she can get if the targets of the Second Five Year Plan are to be fulfilled. The proportion of *commercial* energy—that is to say, coal, electricity and oil—to the whole energy system is still extremely low in India. Nevertheless, it is beginning to have its impact on traditional methods and ways of life, even in remote rural areas.

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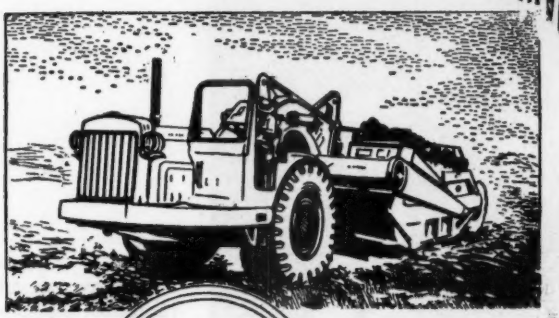

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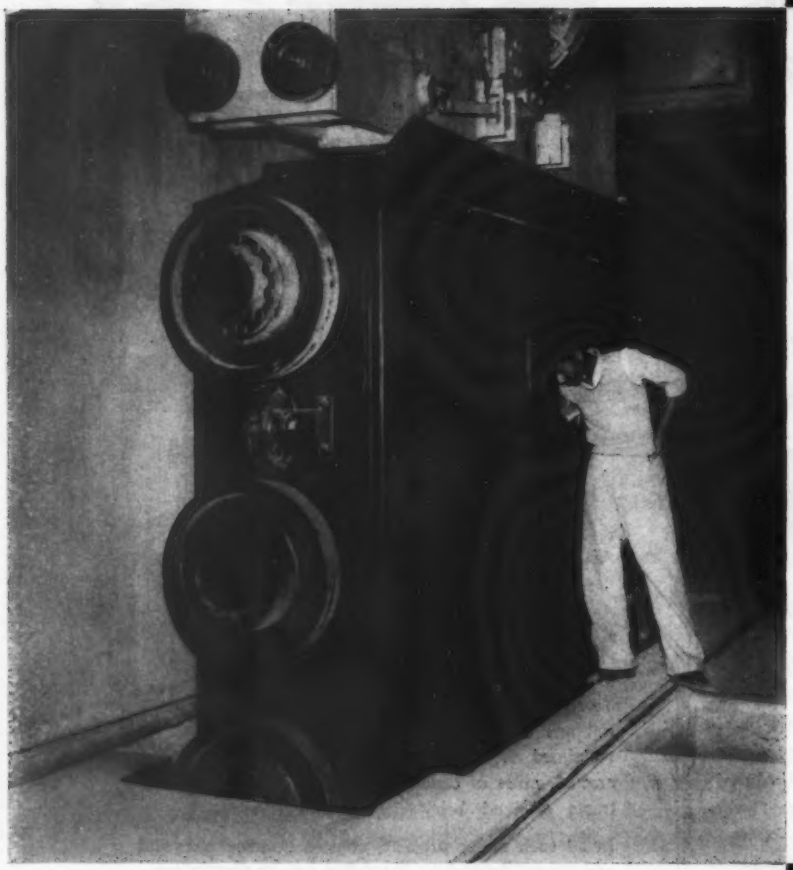

Part view of one of the Hirakud Deep Sluice Gates in lifted position
Gate size:
12′ width, 20′ height

For the Bhakra-Dam
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has under construction
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Water Head:
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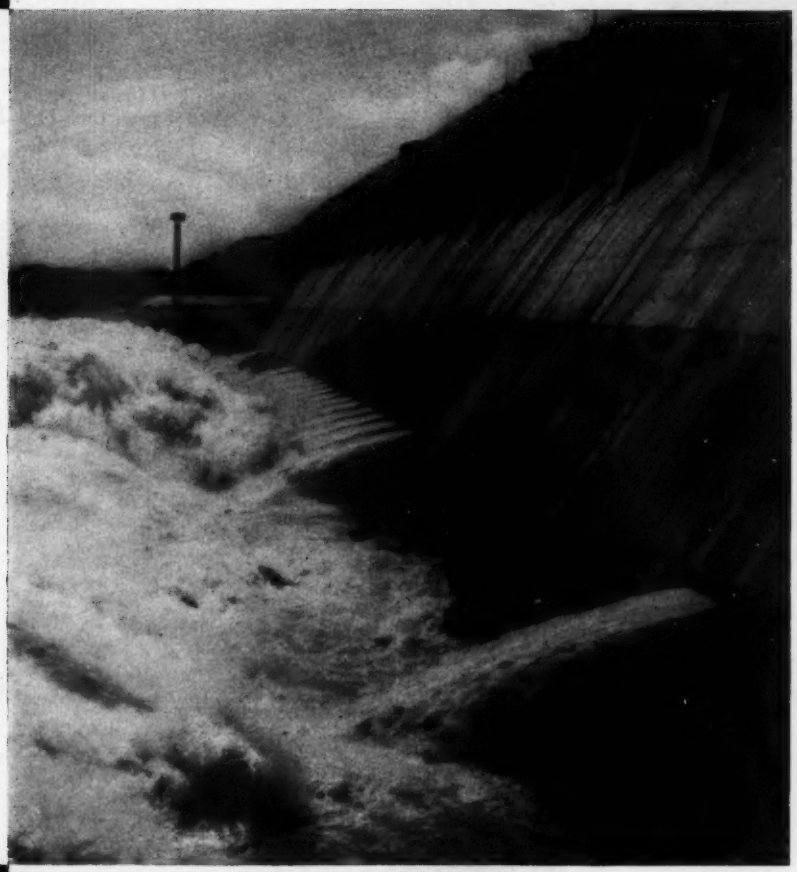

**Part view of
Hirakud-Dam
with some Deep Sluice
Gates opened
Water Head:
120'**

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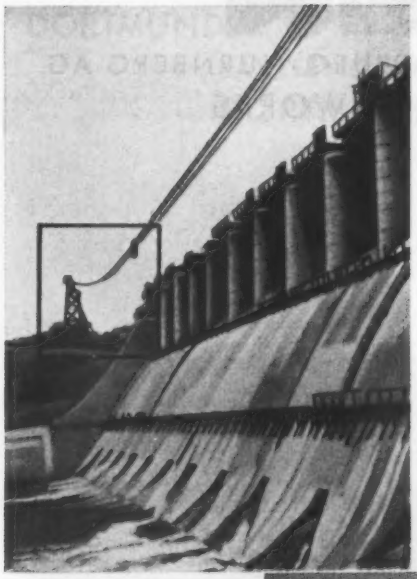

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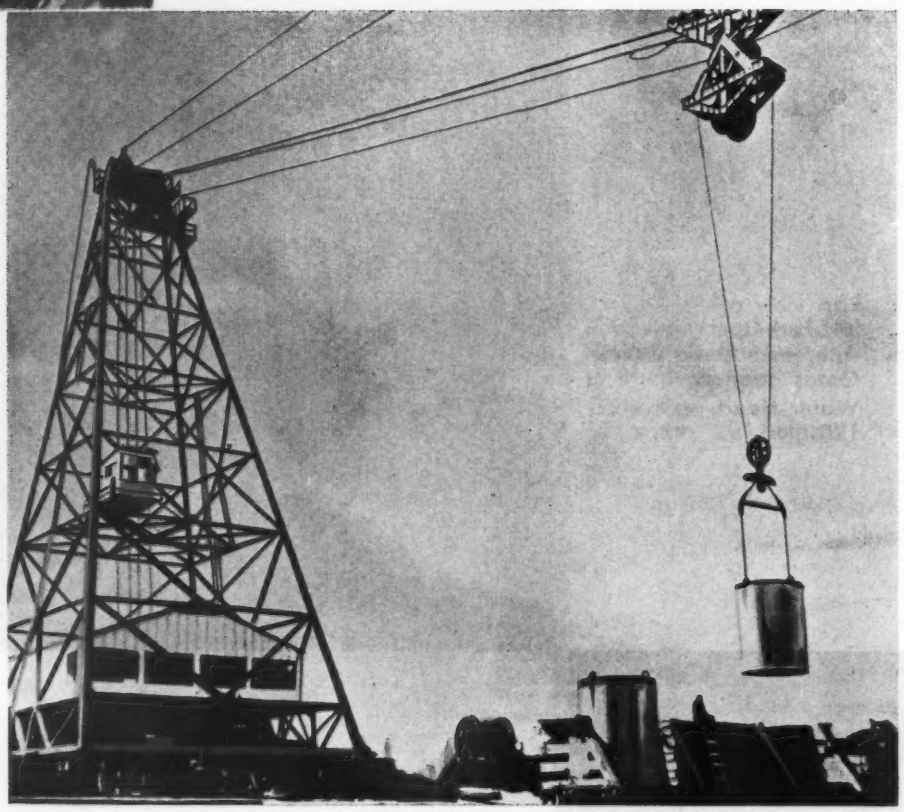
TRAVELIFT OPERATION showing concreting buckets at loading transfer point. Empty bucket being returned to Larry car. Full bucket awaiting pick-up.



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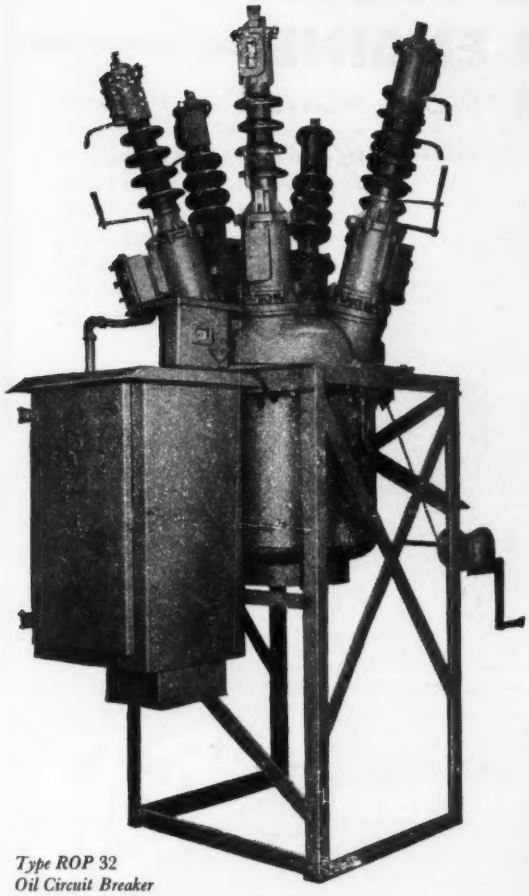


Type ROP 32
Oil Circuit Breaker

When the dam is built and the major constructional work completed the task of installing the electrical plant and the equipment must be undertaken.

Ferguson Pailin have supplied switchgear for indoor and outdoor stations, including major hydro-electric schemes the world over. 'F. P.' is synonymous with first-class design, manufacture and performance of this essential equipment, ranging from extra high voltage switchgear for main grid supply systems down to low voltage switchgear for industrial purposes.

Two examples of 'Ferguson Pailin' switchgear, for varying duties, are illustrated here. They are :—

ROP 32 OIL CIRCUIT-BREAKER

Wherever 22 kV or 33 kV outdoor oil circuit-breakers for breaking capacities up to 750 MVA are required the merits of the 'ROP 32' breaker should be considered.

The design of this breaker provides for the optimum protection against adverse working conditions peculiar to countries in various parts of the world as well as maximum resistance to the effects of fluctuating temperatures and humidity.

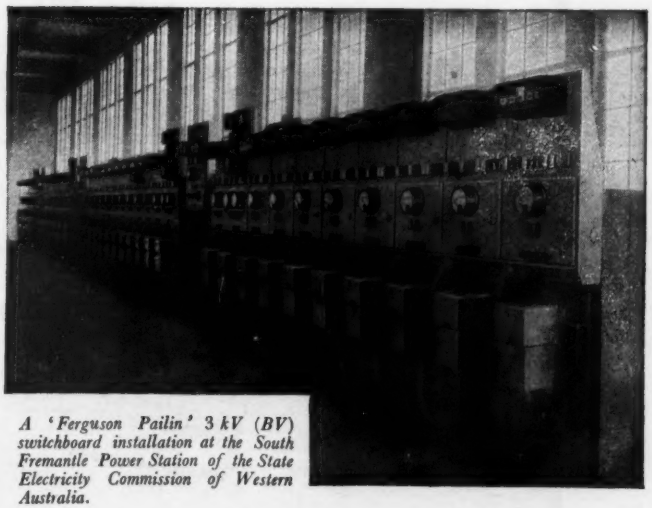
The versatility of the 'ROP 32' makes it remarkably adaptable to local requirements. Complete dependability and reliability make it a natural choice for incorporation into any scheme involving the transmission of power at 22 kV or 33 kV.

The circuit-breaker tank is of cylindrical shape and all three phases are brought into one tank, permitting the use of smaller framework thereby achieving compactness.

'BV' SWITCHGEAR

'Ferguson Pailin' Type BV switchgear is of the completely enclosed metalclad type. It is constructed on the unit principle and can readily be extended by units of similar rating, or by metalclad oil switches.

Vertical isolation of the breaker ensures minimum space requirements of the unit, whilst adequate interlocks safeguard against mal-operation.



A 'Ferguson Pailin' 3 kV (BV) switchboard installation at the South Fremantle Power Station of the State Electricity Commission of Western Australia.

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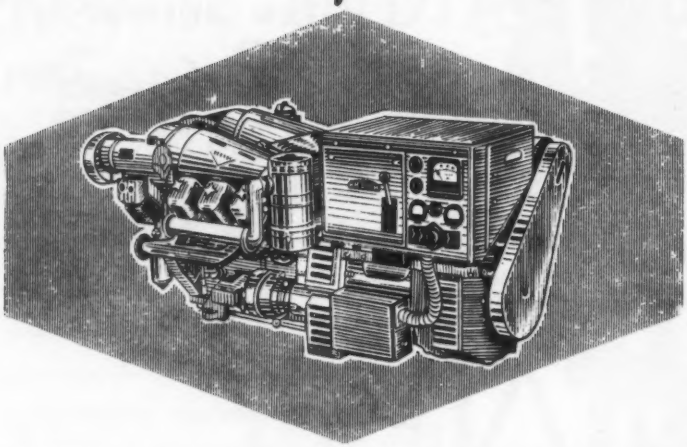

THIS ILLUSTRATION SHOWS A PETTER-McLAREN PDV6 AIR COOLED DIESEL ENGINE RUNNING AT 1500 R. P. M. WITH A BRUSH 39.5 KW. AMPLIDEX CONTROLLED ALTERNATOR.

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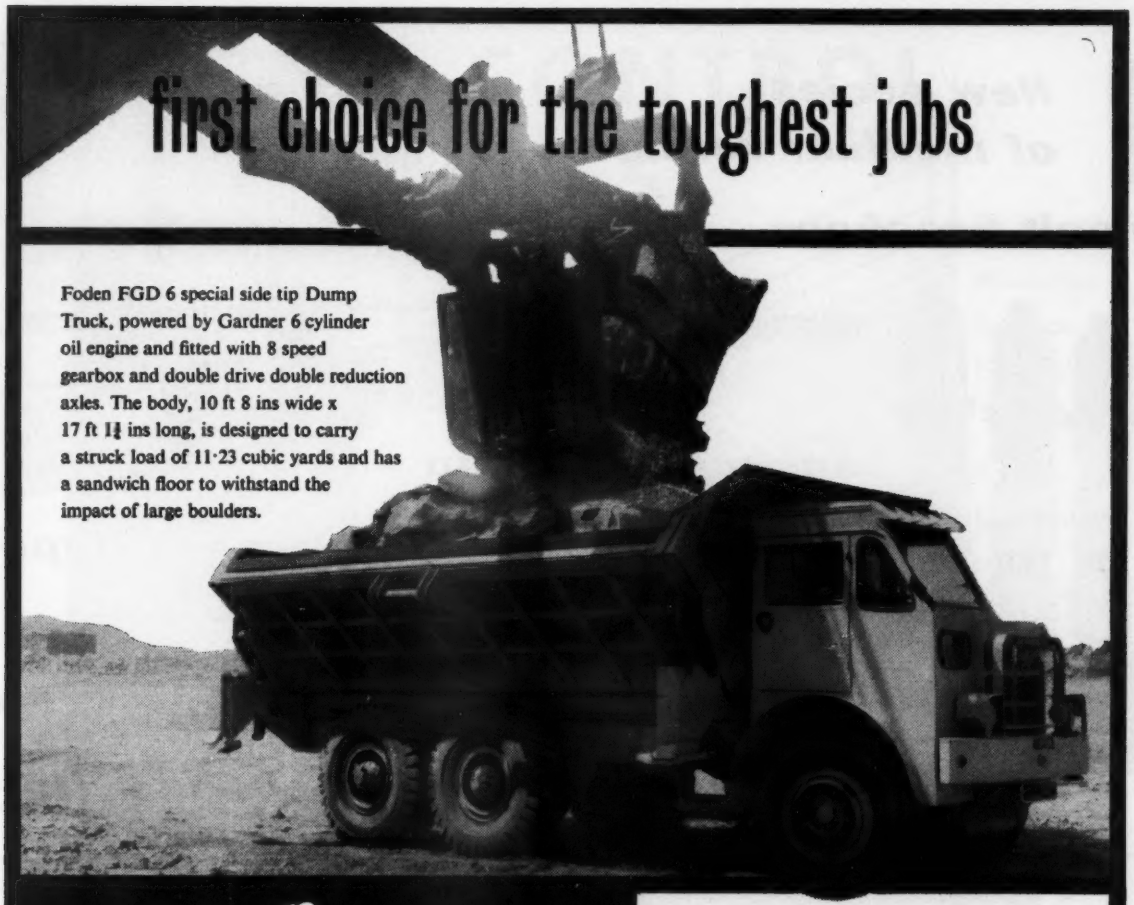

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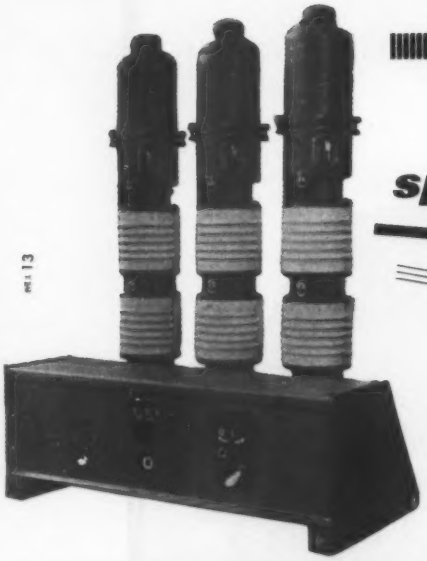

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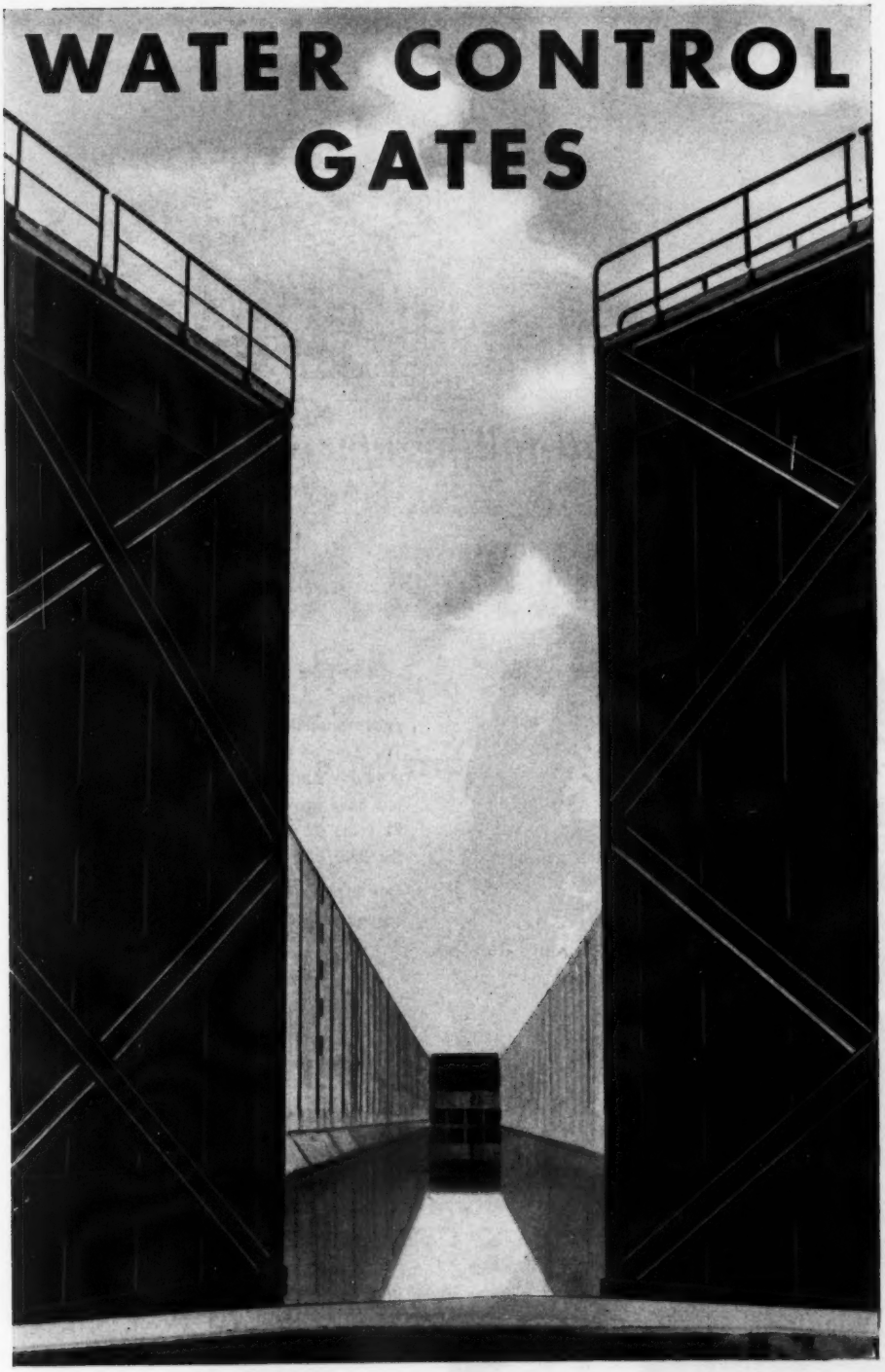

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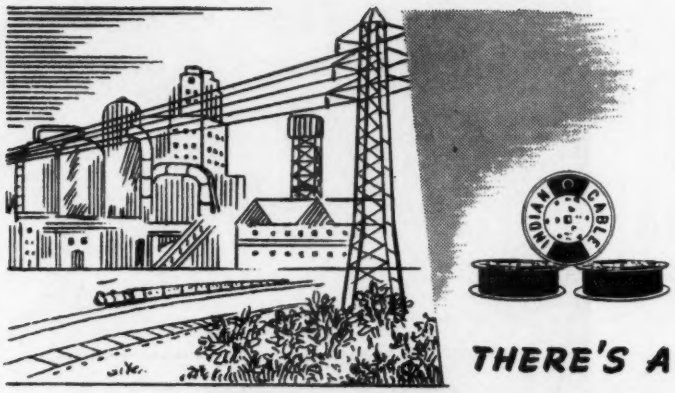

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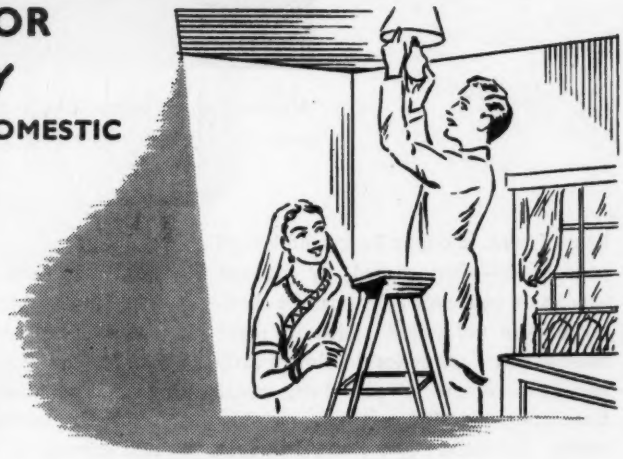

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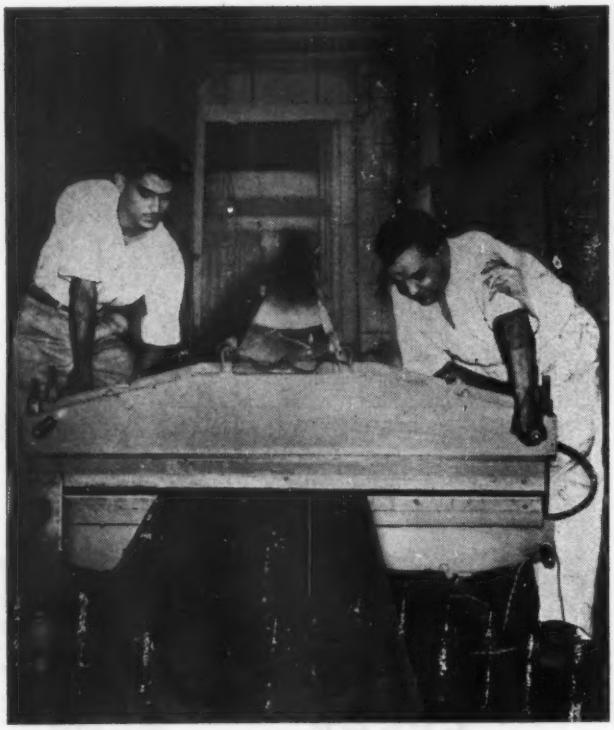

Members of a Dunlop Mobile Splicing team splicing a conveyor belt on site.

Breakdowns, idle man hours and loss of production—often caused by fastener trouble on conveyor belts—can be eliminated by a vulcanised splice to make endless belts. A splice develops nearly the full strength of the belt, metal fasteners only 50%. It cannot, like metal fasteners, give way without warning Splicing reduces noise and friction, increases transverse flexibility at the joint which ensures uniform troughing throughout the belt, and minimises loss of strength at the joint which may permit a thinner and less costly belt to be used.

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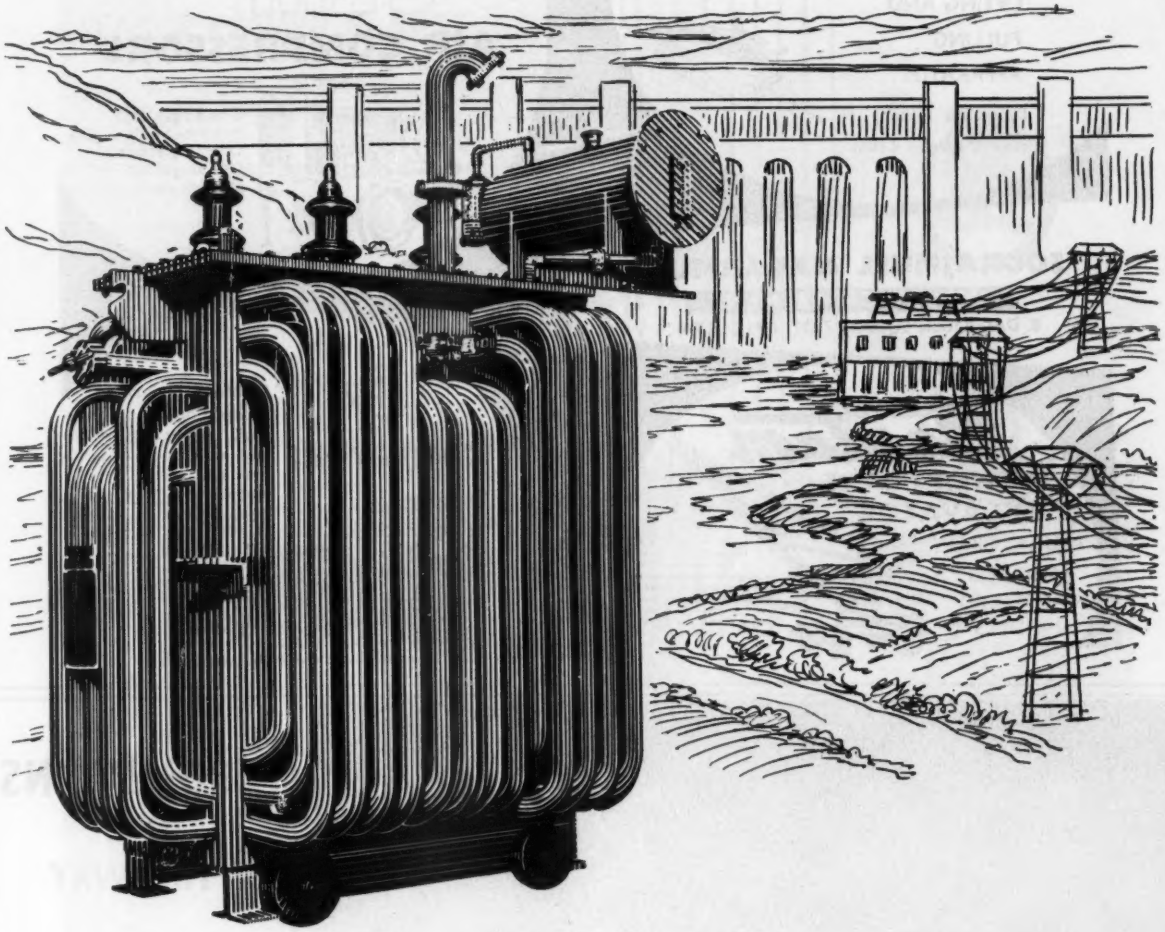

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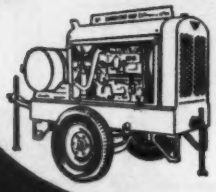

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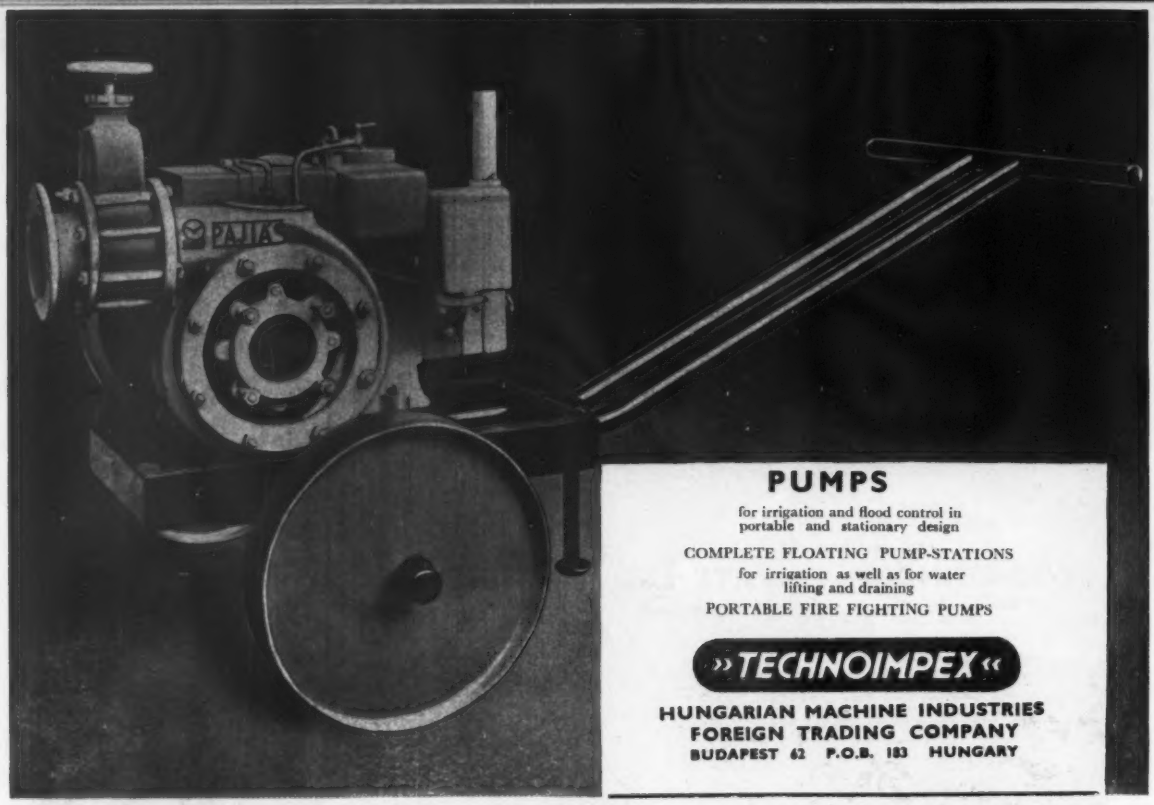

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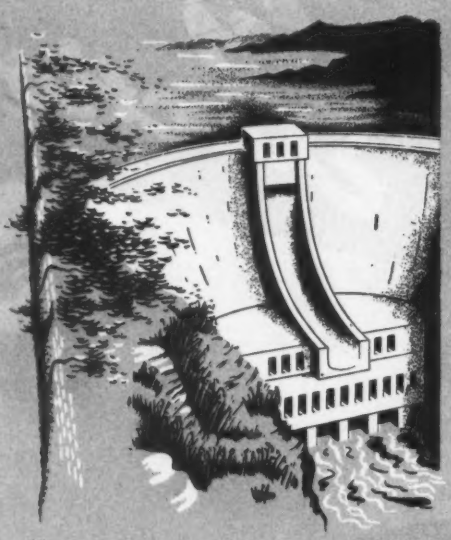

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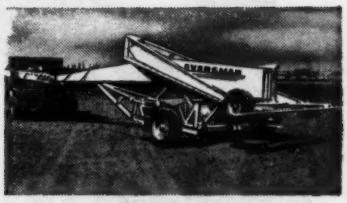

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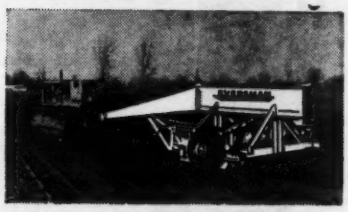

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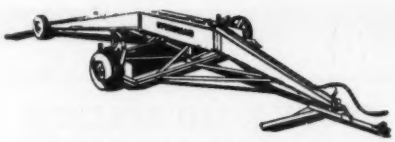

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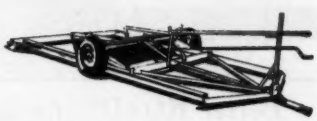

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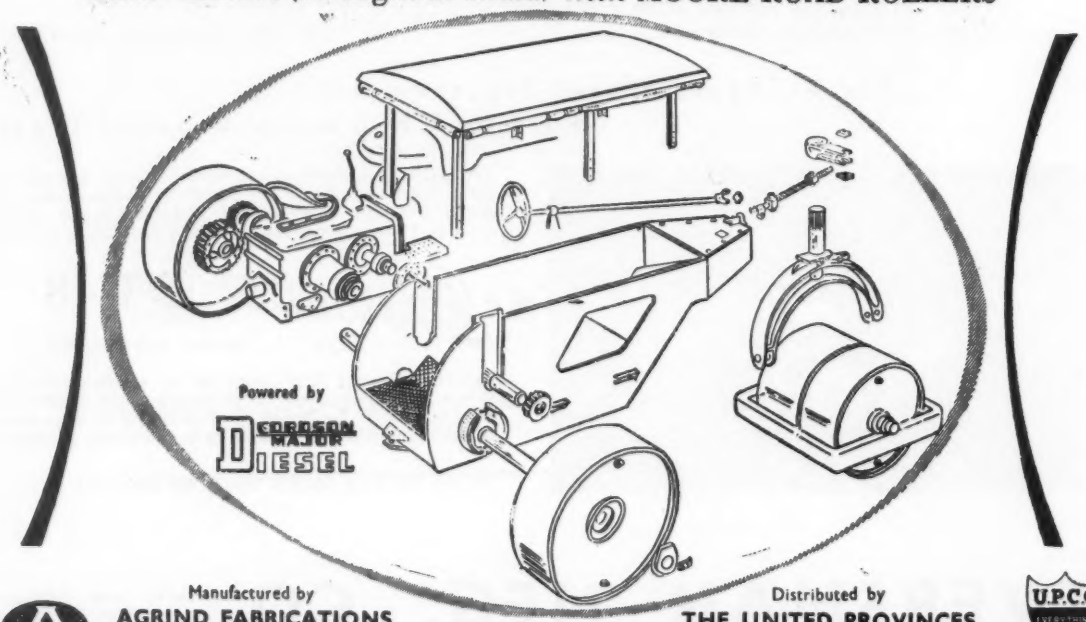

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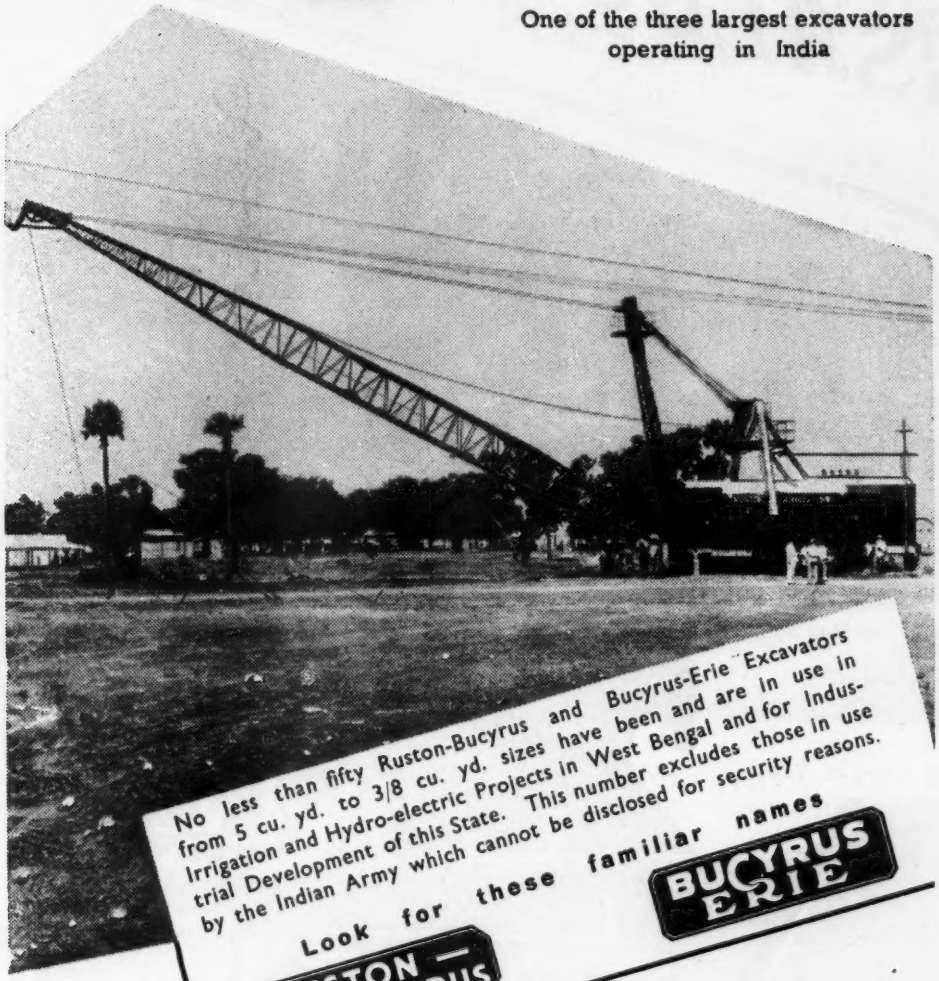

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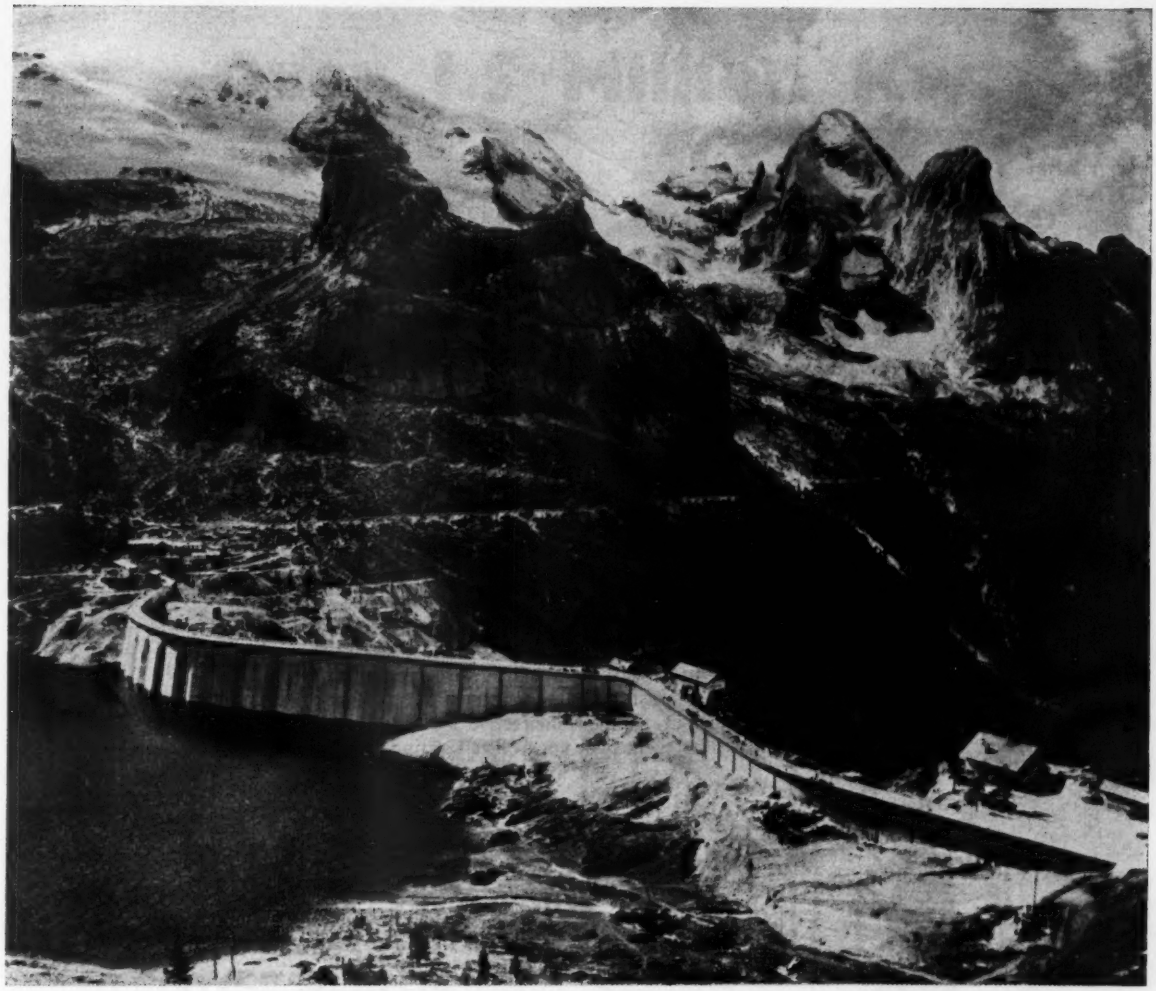

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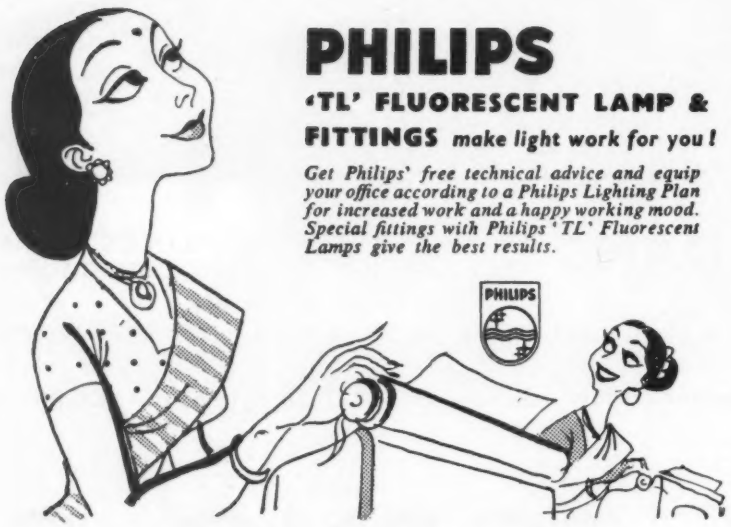

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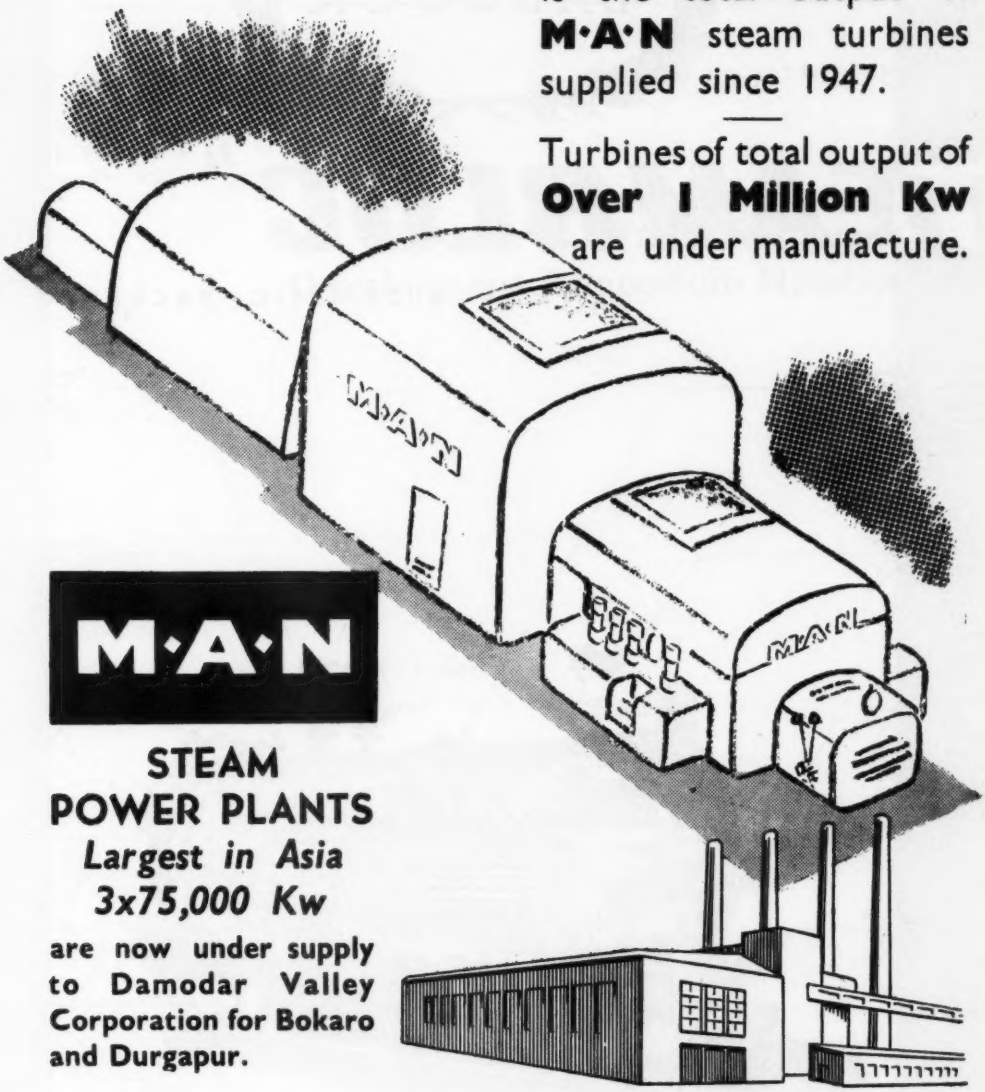

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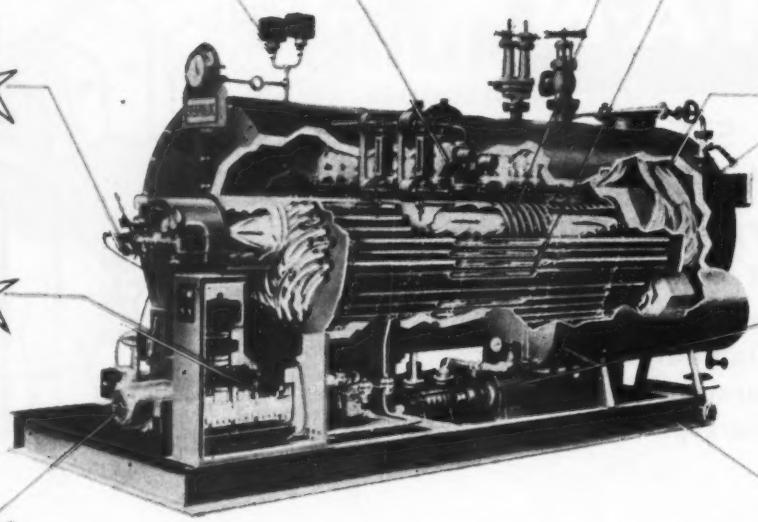

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A MONTHLY DEVOTED TO DEVELOPMENT OF POWER & WATER RESOURCES IN ASIA

Editor : K. K. Sinha

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VOL. VII NO. 9
September 1957

W. B. Power & Water Resources Development Symposium Number

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Message

I am glad to note that the Indian Journal of Power and River Valley Development is bringing out a 'Special Number' containing the deliberations that took place in the Symposium on the Development of Power and Water Resources of West Bengal held during the last session of the Indian Science Congress in Calcutta. The publication contains a collection of well-thought articles contributed by a group of scientists and engineers who are united in their desire to see the quickest possible application of science and technical advances for the benefit of mankind.

It must be emphasized that the responsibility for development and application of science in a democratic country like ours rests ultimately on its citizens without whose full co-operation no Development projects could be fully implemented.

The 'Special Number' presents the statements and opinions of different contributors indicating various development possibilities in West Bengal, and I hope that in the not distant future these ideas of scientists and engineers would become a reality.

B. C. Roy
President, Indian Science Congress
1956-57

Symp

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Dr. B. C. Roy, President of the Indian Science Congress, inaugurating the Symposium. Mr. K. K. Sinha, Editor of this journal, is on his right and Mr. Ajoy Mukherjea, Chief Guest, is on his left.

One of the most successful symposia held under the auspices of the Indian Science Congress in 1957 was on "Development of Power and Water Resources of West Bengal" sponsored by the Indian Journal of Power and River Valley Development. It was held at the University College of Science premises at 92, Upper Circular Road, Calcutta during the Annual Session of the Congress. The Symposium was inaugurated on January, the 17th. by Dr. B. C. Roy, the General President of the Science Congress for the year 1957. Dr. G. P. Chatterjee, Ph.D (Met), Ph.D (Physics), M.A.S.M., Professor and Head of the Department of Metallurgy, Chemistry, Fuel and Geology, Bengal Engineering College, Howrah, and Sectional President for Geology and Engineering, Indian Science Congress Session (1957), presided. Sri. Ajoy Mukherjea, Minister for Irrigation and Waterways, West Bengal, was the Chief Guest. The Symposium continued for two days in succession.

The object of the symposium was to focus the attention of the public as well as of the whole range of specialists interested in resource development of one State regarding the manifold problems connected with this task as also to have an integral view of the total problem in question, so as to impress upon them the problems, possibilities and perspectives opened up and the interdependent character of the task. We hope that this publication will indicate to what extent this object will be fulfilled.

Subjects

The subjects covered by the Symposium, as finalised, were as follows :

1. Hydro-Meteorological Studies of West Bengal's Rivers.
2. Flood control, Soil Erosion and Silt Problems and the role of Forestry and Soil Conservation.
3. Problems and Possibilities of Irrigation.
4. Possibilities and Prospects of Power in West Bengal, both Thermal and Hydro.
5. Problems and Prospects of Drainage.

A view of one wing of the participants in the Symposium

mposium on

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'est Bengal

Brief Report

Mr. Ajoy Mukherjea, Minister for Irrigation, West Bengal, Chief Guest, addressing the gathering

Originally the problems of the Calcutta Port, Inland Water Transport, and Collaboration with adjacent States were also included. But these were later dropped.

The response to the Symposium has been very good, as can be seen from the very representative character of papers received from specialists of different fields. However, it is neither easy nor desirable to be quickly satisfied. Although we have received unstinted and enthusiastic cooperation from engineers and specialists alike, we do think that the material gathered here is not complete in any sense of the term, though it does provide a broad view of the complex totality.

Dr. B. C. Roy's Address

Dr. B. C. Roy, in the course of his Inaugural Address, called upon the engineers and scientists to devote themselves to the bringing about of economic independence of the country. He said that irrigation and cheap power were the two main factors for the building up of a good economy. So far as West Bengal was concerned they had problems which required to be carefully looked into. Many West Bengal rivers had become silted up as a result of which large tracts of land had become water-logged or had dried up. The problem of the Sunderbans was a major issue.

He further explained that rivers which fell into the sea, including the Hooghly, used to be fed by water from upland areas. Gradually with the moving of the course of the river Ganga between Murshidabad and Malda, the flow was now cut off except for two or three months during rainy season. Communication between different parts of India through Ganga had also been cut off.

With the cutting up of upland water, Dr. Roy said, beds of the Sunderbans rivers were gradually rising and the bunds which were satisfactory in the past had now become less and less efficient for the purpose for which those were meant. The cost of embankments became higher as the river beds also became higher and higher. This had resulted in a vicious circle. West

Another wing of the Symposium

Dr. G. P. Chatterjee, Sectional President, Engineering and Metallurgy, Indian Science Congress Session, 1957, who presided over the Symposium addressing the participants.

Bengal had several instances where storm and cyclone resulted in the innundation of large areas. It was upto engineers to find out how to bring about engineering arrangements so that upland water might again flow in the deltaic rivers.

Dr. Roy said that cheap power was necessary for development of cottage industry. "Our country is not rich but we want to be rich. By utilising their knowledge and intellect and helping us to have cheap and better irrigation, the engineers can help us in implementing our objectives in the Second Five-Year Plan", Dr. Roy said. He also emphasized that co-operation between the Government, the engineers and the people would help them achieve the target they had set before them.

The attendance to the Symposium was over 200, representing officers from the Government of West Bengal's departments of Irrigation, Electricity, Agriculture, Forestry, Industries as well as those from the Central Water and Power Commission, the Geological Survey of India, the Meteorological Department, the Fuel Research Institute the Damodar Valley Corporation, Geology and Geography Departments of the Calcutta University and of other Colleges in Calcutta and a large number of independent scholars, businessmen and others.

The discussion was uneven in character and some of the important questions which developed special interest have been recorded in this volume together with the replies of the authors at the bottom of the paper in question.

The Journal wishes to express its thanks and gratitude to all the participants, and specially to Dr. Roy, for their kind cooperation in making the Symposium a success. It also records its deep gratitude to the Indian Science Congress to enable this important function to be accommodated within their busy programme at very short notice.

We hope that this special number may prove a worthy book of reference to all concerned in the development of our country.

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A Century of Resource Development

By AJOY MUKHERJI

IN this State we have always looked upon rivers as our mothers—"নদী-মাতৃক দেশ—"so the saying goes. Our poets, Bankim Chandra, Rabindra Nath and others have associated the beauty and bounty of Nature with the flowing streams which are the lifesprings of this land. The health and prosperity of the people are intimately associated with the co-ordinated development of the river system of this country. Rivers irrigate the lands, fertilise them with silt and help them to produce bumper crops which, again, they carry to the different parts of the country. Thus rivers in Bengal have formed from time immemorial the main source of her wealth and happiness. They are the main arteries of this country.

With the dawn of the present century the idea of "Resource Development" has become increasingly prominent. We have now grown used to look upon "Rivers" as resources to be developed in the same way as we have been developing previously iron, coal or any other minerals. We in West Bengal have been fortunate in having Nature's bounty in plenty. Our lands are fertile, our mines are full of coal and iron, our forests are rich with valuable timber and our rivers carry enormous volume of water and fertilising silt. There is no dearth in nature's gifts. They have to be properly harnessed.

The twentieth century has been pre-eminently a century of "Resource Development." Though human civilisation has always progressed with the development of Nature's resources, the present century has witnessed these advances in such rapid strides that within the last fifty years the world has seen enormous changes as were never seen in the rest of the period of human existence. Development of steam power, discovery of natural resources such as coal and oil and their application to internal combustion engines leading to phenomenal rise in the speed and comfort of transportation by land, sea and air, utilisation of water power in multi-purpose River Valley Projects, and, to crown all, the discovery of Atomic Energy have brought to humanity the promise of a glorious future, full of health, wealth and happiness.

In West Bengal, our Power and Water Resources are plentiful and varied. In the north, in the sub-mountainous tracts of the Himalayas, we have such mighty hill streams as the Teesta, Jaldhaka, Torsa, Rydak and Sankosh. They are vast potential sources of hydel-energy and irrigation water supply. In this tract we are short of coal or oil and the whole region has to depend for its energy supply on timber fuel that is obtained by felling trees in the forests of the Terrai and the Dooars and also in the hilly uplands. This indiscriminate destruction of soil cover and felling of trees surreptitiously by the local people have created such a widespread denudation of the forest areas during the last World War that we have witnessed during the last few years widespread destruction of land and crops by extensive floodings and sandings. It is hoped that this problem will be successfully tackled by the engineers and scientists who are now devoting their attention to this region. I find some of the speakers in the Symposium are speaking on this subject. They will indicate some useful lines of action. The problems are serious and demand immediate attention.

One of the potential sources of energy in West Bengal in the deltaic region is the tide. I understand in very few countries of the world this source of energy has been as yet successfully tackled. In the estuaries of Hooghly, Thakuran and Rai Mangal in the Sunderbans, the range and strength of the tides are enormous and if properly harnessed may yield energies that are badly needed in this area. I hope, our scientists and engineers will also direct their attention to the development of this source of energy.

The development and distribution of cheap power is essential to a country where drainage congestion is chronic. The last September flooding have underlined this aspect of our problem very prominently. We may succeed partially in removing this congestion by cleaning and proper alignments of the drainage channel; but the outfalls of all these channels being tidal, we may have to resort to intensive pumping which has been found so successful in low countries like the Netherlands. I hope, our scientists and engineers will also explore the possibility of drainage improvement by pumping.

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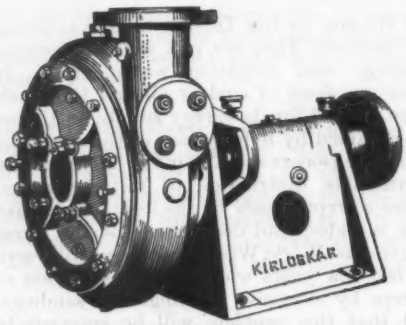

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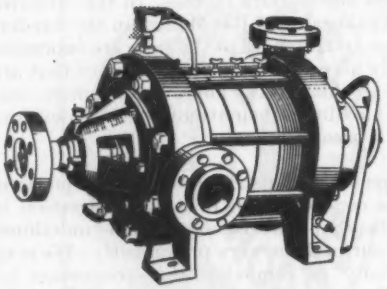

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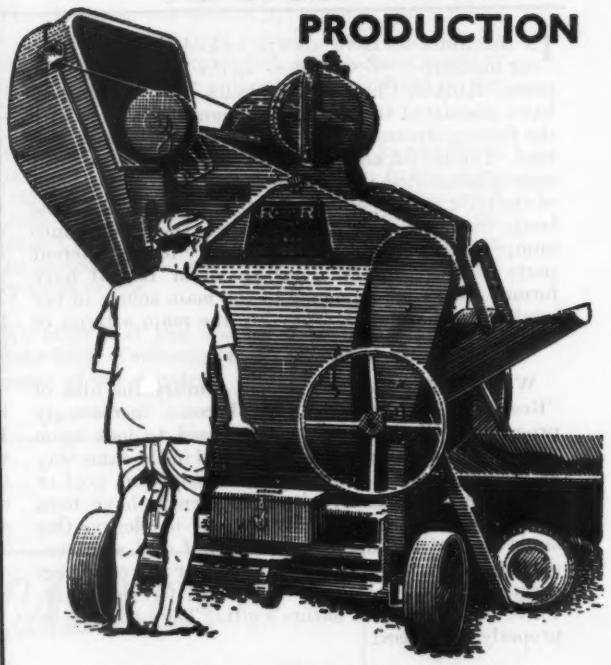

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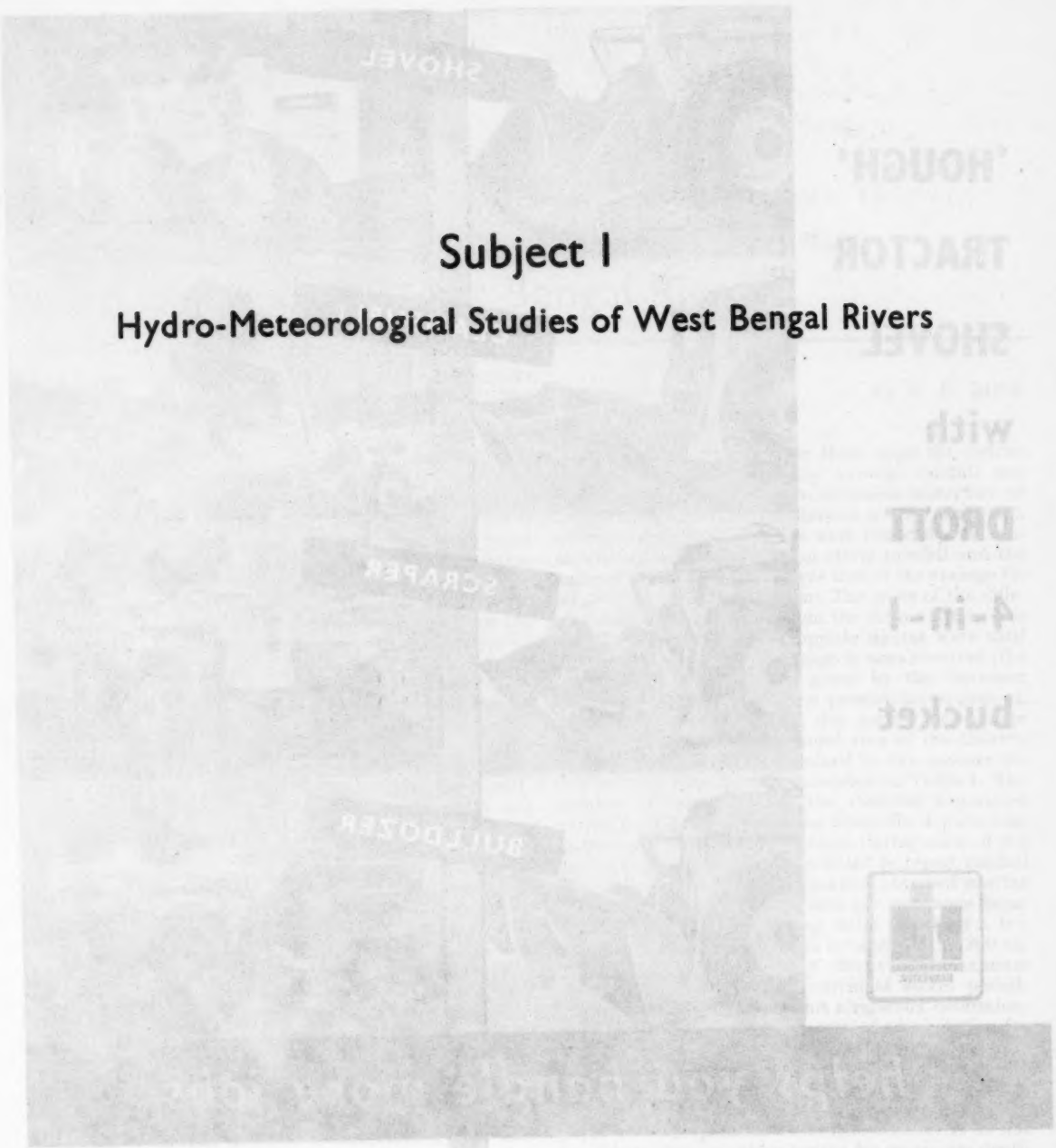
Subject I

Hydro-Meteorological Studies of West Bengal Rivers



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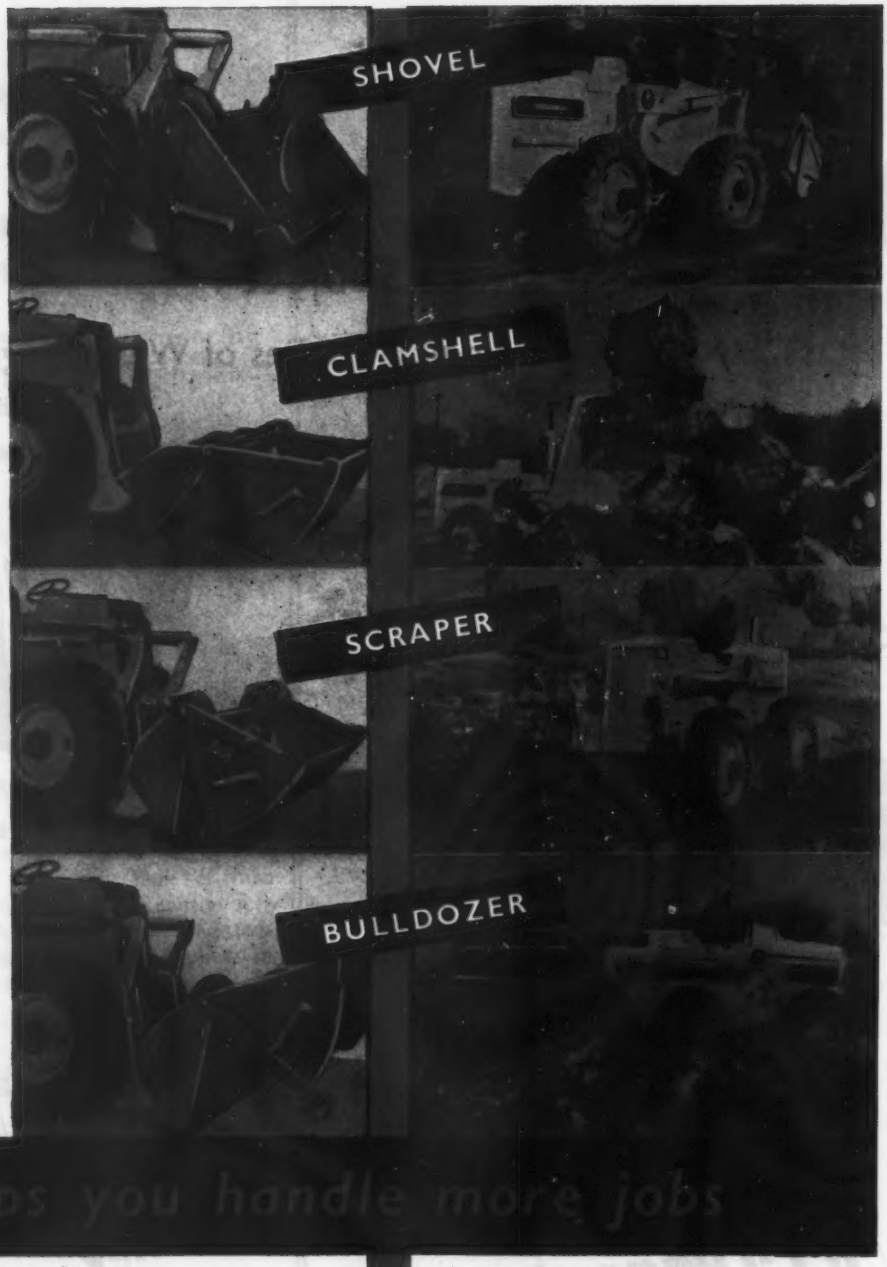

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Preliminary Meteorological Study associated with West Bengal Rivers*

By U. K. BOSE

IT is widely recognized that limit of meteorological phenomena rarely conform to political boundaries. The area of West Bengal is so restricted that any synoptic meteorological study confined entirely within its bounds will not be fruitful. If the rainfall pattern as obtainable from the daily rainfall data recorded at all the existing raingauge stations of West Bengal are examined and similar data from contiguous areas is combined with it, some tentative results of some significance may be obtained. In this investigation the first point that was taken up was an assessment of the effectiveness of such an approach which would justify the undertaking of any further work on the same lines. The second point was to see if any useful results could be obtained, even tentatively and subject to further confirmation and corroboration. With these objects in view the rainfall tables of West Bengal from 1933 to 1954 were considered confining only to the south west monsoon season periods and a certain number of "storm periods" were selected for scrutiny. The selection of the period was made from the departmental publications, Weekly Weather Reports and Monthly Rainfall of India. Seven-day periods, during which the rainfall was in excess of the normal by more than 50% over either S.H.W. Bengal or Gangetic West Bengal were considered to be "Storm periods". 47 such 7-day periods were chosen for closer examination. The daily rainfall at all the available stations in the different districts of Bengal during the chosen period disclosed on examination that in more cases the rainfall was randomly distributed over the days of the period considered. And if on occasions three to five days periods of marked heavier rainfall could be demarcated these did not extend over any extensive area nor did they show any clear sequence of movement from one part of the area to another. Thus it will be seen that the term "Storm-rainfall" as used here is somewhat different in connotation from that used in temperate and sub-tropical areas in other countries such as U.S.A. In the present work all the daily rainfall data available in the printed rainfall tables were used to find the district average rainfall for all the districts for the seven day period under consideration. The averages thus found were plotted on a map of West Bengal. One such map is shown as an illustration. Fig. 1. From these maps the district or districts whose seven-day average rainfall was highest were marked off. On occasions when two or more contiguous districts showed nearly same high average rainfall the districts were considered to constitute one area of maximum storm rainfall and the value of rainfall considered was that of the average for all such districts put together. The areas of the different districts were taken from the census (1951)—for period prior to 1947, appropriate figures were used for the districts where a change in area occurred (the values of district area as given by the Surveyor General were adopted in the present investigation). Thus for each chosen seven day period the average maximum rainfall and the total area of the district, or districts involved, determined in the manner indicated above have been tabulated in Table I. The number of raingauges in the districts considered varied from 3 to 28 ; also the figure for a particular district was not the same because during some of the chosen periods a few stations failed to report rainfall data. The network of raingauges thus obtained was far from being satisfactory, the area per raingauge being of the order of 250 to 500 sq. miles except at a few districts where the area ranged between 100 to 200 sq. miles. Although the values of the average maximum rainfall and the area for individual storm periods given in Table I do not permit a rigorous determination of the maximum depth area of precipitation for the storms yet it does give, in a qualitative way, an idea of the average maximum precipitation and the area over which the same extended. All the cases tabulated above were plotted on a semi-logarithmic paper and the plot shows a wide scatter. It is not possible to draw envelope curves for maximum depth area duration on this diagram, as has been done by many workers, for example Horton who obtains an exponetial relation between the maximum precipitation and storm area (Horton R.E., Discussion on Distribution of Intense Rainfall, Tran. A.S.C.E. Vol. 87 pp. 578-585, 1924). Figure II shows this diagram. This diagram was used to prepare a histogram (fig. II fig. III) of the frequency of storms, for classes each of area intervals 1,000 sq. miles. The largest number of cases occur in the classes 3000-4000sq. miles (14) and 2000-3000sq. miles (13). The mean rainfall for the

*This work was done under one of the Schemes of Flood Control project in the Hydrology Section of the Office of the Director General of Observatories. The method of approach adopted by the author is somewhat different from the standard method for such enquiries.

former is found to be 11.73 inches with a standard deviation of 4.36″ and the latter gives a mean of 15.34″ with a S.D. 5.15″. The histogram is also interesting in as much as it shows a typical normal distribution with the skewness so commonly encountered with rainfall amounts and the most significant feature is the occurrence of a certain number of exceptionally large area-storms which fall completely outside the area-range of the main bulk of storms. But because of the limited number of cases and the limited validity of the method of determination of the area further statistical analysis of the histogram has not been pursued.

From the two most frequently occuring classes of storms all storms occuring in each class were separately averaged to give two hypothetical storms as representative of each class. The rain water involved in these two hypothetical storms can be assessed and may preferably be expressed in run off units to enable easy comparison with Hydrological observations. Table II gives the figures obtained :

TABLE II

S. No.	*Average rainfall*	*Average area in sq. miles*	*Rainfall expressed in run-off units*
1.	15.34	2,490	1,46,713 cu. sec.
2.	11.73	3,595	1,61,972 cu. sec.

It will be seen from Table II that the rain water involved in these "hypothetical storms" is quite comparable with the average run off encountered in the main rivers which bring their water into West Bengal during the monsoon season. Further we have to remember that only a fraction of the rain water involved in these hypothetical storms will actually appear as surface run-off in the rivers of the basins involved.

In order to pursue the matter a little further two of the selected periods were examined in some detail. The periods chosen were 10th to 16th July, 1952 and 8th to 14th June, 1950.

All the available seven day rainfall for stations in Bengal were used to obtain the daily average rainfall for each day of these periods for the districts where the maximum rainfall had occurred. Fig. IV represents these daily average rainfall. The co-efficient of variation for each day were also calculated and are shown in Table III. It will be seen how in the case of the July, 1952 storm the rainfall was spread over the entire seven-day period. In the case of the June 50 storm a noticeable variation is seen during five days of the period. Also the maximum rainfall occurred on different dates over south west Bengal and S.H.W. Bengal, but no sequence could be traced through the central parts of West Bengal. The rainfall for the seven day periods at each of the stations were plotted on a map. These were supplemented by plotting rainfall data from few contiguous stations in Bihar and Sikkim. Then isohyets were drawn and the area over which the maximum rainfall occurred was determined with a planimeter. This enabled us to determine

TABLE III

Storm period 10th to 16th July 1952

Date	*District Jalpaiguri and Cooch Behar*		*Seven districts as listed below.*	
	Mean daily rainfall	*Coefficient of variation* $\frac{S.D.}{Mean} \times 100$	*Mean daily rainfall*	*Coefficient of variation* $\frac{S.D.}{Mean} \times 100$
10th	3.53	61.47	0.79	106.3
11th	4.82	57.3	1.30	96.9
12th	3.93	100.0	0.71	122.5
13th	4.61	52.49	1.04	126.9
14th	0.14	157.14	0.95	113.7
15th	0.13	246.15	0.46	131.9
16th	0.07	150.0	0.61	167.2

1. Darjeeling 2. West Dinajpur 3. Malda 4. Murshidabad 5. Burdwan 6. Hooghly 7. Howrah.

Storm period 8th to 14th June 1950.

Date	*District Jalpaiguri and Cooch Behar*		*District Midnapur*	
	Mean daily rainfall	*Coefficient of variation* $\frac{S.D.}{Mean} \times 100$	*Mean daily rainfall*	*Coefficient of variation* $\frac{S.D.}{Mean} \times 100$
8th	0.43	151.1	0.02	385.0
9th	0.22	254.5	0.25	392.0
10th	0.18	172.2	3.62	94.5
11th	2.08	95.1	2.52	84.1
12th	6.62	62.5	0.70	97.1
13th	2.96	82.1	0.80	125.0
14th	0.81	118.5	0.38	150.0

roughly the depth area of rainfall for the storm, and also to make an assessment of the rain water involved expressed in run off units, table IV gives the relevant figures.

TABLE IV

S. No. Storm	*Run off estimated from max. average Dist. rainfall.*	*Estimated from isohyetal maps.*
1. (*a*) 10th-16th July 1952.	2,40,101 cu.sec.	2,47,782 cu.sec.
(*b*) 10th-16th July 1952 (Gangetic West Bengal)	2,60,742 cu.sec.	2,18,303 cu.sec.
2. 8th-14th June 1950.	4,45,684 cu.sec	7,23,499 cu.sec.

The order of magnitude of rain water involved in the first storm is comparable with that of the hypothetical storms referred to previously. Whereas the assessment of the rain water by the isohyetal methods and district average methods are in reasonable agreement in the case of the storm of 1952, the agreement may hardly be called good in the case of the second storm namely that of 1950.

The hydrological data for the river Tista and Torsa for these periods as obtained from the Executive Engineer, West Bengal are shown in Fig. V.

An examination of Table I shows that the selected storms can be divided into two classes depending on the area where the maximum rainfall area happens to fall. The first and the larger of the two classes is the one in which the maximum rainfall area is over Sub-Himalayan West Bengal and the other group is constituted of the storms in which the maximum rainfall is confined to central and southern West Bengal. Only on a few occasions the maximum rainfall area lies over both S. H. W. Bengal and Gangetic West Bengal. It is also seen that a fairly larger number of storm periods of the first kind (i. e. maximum precipitation occuring over S.H.W. Bengal) coincide with periods when floods have been reported based on hydrological and other observations. This would indicate that a more detailed examination of storm period rainfall, (either seven day period or shorter periods whenever possible) may be worthwhile. Such study may enable us to make more definite assessment of rain water involved in these storms which would ultimately enable us to make at least rough estimate of surface run offs, occuring during the storms periods. But before such studies are undertaken it is necessary that rainfall data recorded over a close network and extending to the portion of the basin within the Himalayan ranges, specially Sikkim, should be available and the rainfall data should extend over a fairly large number of years. For more exact and quantitative studies it is also very necessary to have some record, extending over reasonably large number of years, of rainfall intensities experienced in this area which at the present moment is almost absent.

Recently the West Bengal Govt. has agreed to finance a scheme for opening 26 raingauge stations in North Bengal. The addition of these stations would certainly improve the network in this area and when rainfall data for a number of years is collected from the enlarged network useful work may be done with the same.

It may perhaps be added before concluding this paper that a cursory examination of the isohyetals for the storm rainfall associated with the much publisized floods in North America during 1955 and 1954 seem to suggest that the rain water associated with the storms in question were of less or at the most comparable order of magnitude as the rain water associated with storms usually experienced in our area. Therefore, the extensive devastations happening in U.S.A. are to be traced perhaps more to the subsequent history of the rain water after falling upon surfaces and also on the manner of land utilization there. Of course, the above suggestion is subject to confirmation after detailed examination of the storm rainfall.

The scrutiny of data and computation work were carried out by R. K. Das, J. C. Sen, J. P. Gupta, D. K. Nandy and B. C. Jain.

Thanks are due to the Director General of Observatories for permission to submit the paper to the symposium.

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3. Daily rainfall of India (bound annual volumes), compilation by India Meteorogical Department,
4. Daily rainfall of Sikkim stations—unpublished.
5. Collected reports of high and abnormal floods in West Bengal —unpublished.

TABLE I

S. No	*Period of storm-dates and year.*	*Name of District where max. ppt occurred.*	*No. of raingauges whose data have been used*	*Total area in sq. miles*	*Mean rainfall in inches*
1.	1st to 7th June, 1933	Jalpaiguri	7	4296	10.22
		Cooch Behar	5		
2.	24th to 30th June, 1933	Rangpur	9	4827	14.50
		Cooch Behar	5		
3.	21st to 27th Aug. 1935	Jalpaiguri	7	2962	13.06
4.	24th to 30th Sept, 1937	Dinajpur	14	3946	8.85
5.	8th to 14th July, 1948	Jalpaiguri	6	2378	18.65
6.	14th to 20th July, 1949	Darjeeling	5	3538	13.30
		Jalpaiguri	4		
7.	8th to 14th Jun., 1950	Jalpaiguri	6	3712	13.15
		Cooch Behar	5		
8.	10th to 16th Aug., 1950	Darjeeling	5	1160	12.64
9.	17th to 23rd Aug., 1950	Darjeeling	5	3538	11.95
		Jalpaiguri	6		
10.	31st Aug. to 6th Sept., 1950	Jalpaiguri	6	2378	13.23
11.	12th to 18th July, 1951	Jalpaiguri	6	3712	20.42
		Cooch Behar	5		
12.	23rd to 29th Aug., 1951	Jalpaiguri	5	2378	17.36
13.	6th to 12th Sept., 1951	Darjeeling	6	3538	8.48
		Jalpaiguri	6		
14.	10th to 16th July., 1952	Jalpaiguri	5	3712	16.84
		Cooch Behar	5		
15.	31st July to 6th Aug., 1952	Midnapore	22	11119	5.44
		Howrah	2		
		24-Parganas	9		
16.	11th to 17th Nov., 1952	Jalpaiguri	5	2378	5.56
17.	18th to 24th Sept., 1952	Darjeeling	6	6257	10.94
		Jalpaiguri	5		
		Cooch Behar	5		
		West Dinajpur	3		
18.	10th to 16th Sept., 1953	Cooch Behar	4	1334	13.36
19.	24th to 30th Sept., 1953	Darjeeling	4	3538	5.79
		Jalpaiguri	4		

S. No.	Period of storm-date and year.	Name of District where max. ppt. occurred.	No. of raingauges whose data has been used	Total area in sq. miles	Mean rainfall in inches
20.	17th to 23rd Jun., 1954	Jalpaiguri	6	2378	19.21
21.	24th to 30th Jun,. 1954	Darjeeling Jalpaiguri Cooch Behar	5 6 4	4872	11.23
22.	22nd to 28th July, 1954	Jalpaiguri	5	2378	25.71
23.	15th to 21st June, 1934	Jalpaiguri	7	2523	12.71
24.	25th to 31st July, 1934	Jalpaiguri Cooch Behar	6 5	3857	16.37
25.	11th to 17th Jun., 1936	Khulna Backerganj	12 8	9050	5.78
26.	17th to 23rd Aug.,	Jalpaiguri	6	2523	9.86
27.	9th to 15th Jun., 1938	Jalpaiguri	7	2523	17.35
28.	4th to 10th Aug., 1938	Darjeeling Jalpaiguri	6 7	3715	7.43
29.	1st to 7th Sept., 1938	Darjeeling Jalpaiguri	6 7	3715	8.14
30.	22nd to 28th Jun., 1939	Jalpaiguri	7	2523	10.81
31.	8th to 14th Jul., 1939	Darjeeling	6	1192	8.95
32.	16th to 22nd Aug., 1939	Howrah 24-Parganas	3 10	4584	5.97
33.	18th to 24th Jul., 1940	Jalpaiguri	7	2523	21.34
34.	1st to 7th Aug., 1940	Darjeeling Jalpaiguri Dinajpur	6 7 15	7661	5.96
35.	11th to 17th June, 1941	Hooghly Howrah 24-Parganas	8 3 10	5793	11.17
36.	14th to 20th Aug., 1941	Midnapore Hooghly Howrah 24-Parganas	26 8 3 10	11057	9.14
37.	8th to 14th July. 1942	Midnapore Howrah 24-Parganas	26 3 9	9851	5.06
38.	24th to 30th Jul., 1942	Darjeeling	5	1192	4.63
39.	1st to 7th Aug., 1942	Khulna Pabna Faridpur Bakerjganj	11 4 8 8	13170	6.35
40.	5th to 11th Aug., 1943	Darjeeling Jalpaiguri	5 6	3715	7.87
41.	23rd to 29th Sept., 1943	Jalpaiguri	6	2523	14.25
42.	24th to 30th Aug., 1944	Bankura Burdwan Hooghly	25 6 8	6583	9.05
43.	16th to 22nd Aug., 1945	Jessore Khulna Bakerganj	5 11 4	11255	6.51
44.	6th to 12th Jun., 1946	Jalpaiguri	6	3050	8.35
45.	4th to 10th Jul., 1946	Jalpaiguri	6	3050	17.23
46.	11th to 17th Jul., 1946	Bankura Midnapore	23 13	7917	5.71
47.	1st to 7th Sept., 1947	West Dinajpur Malda Murshidabad	1 4 9	4888	5.97

Facing page 12

FIGURE I

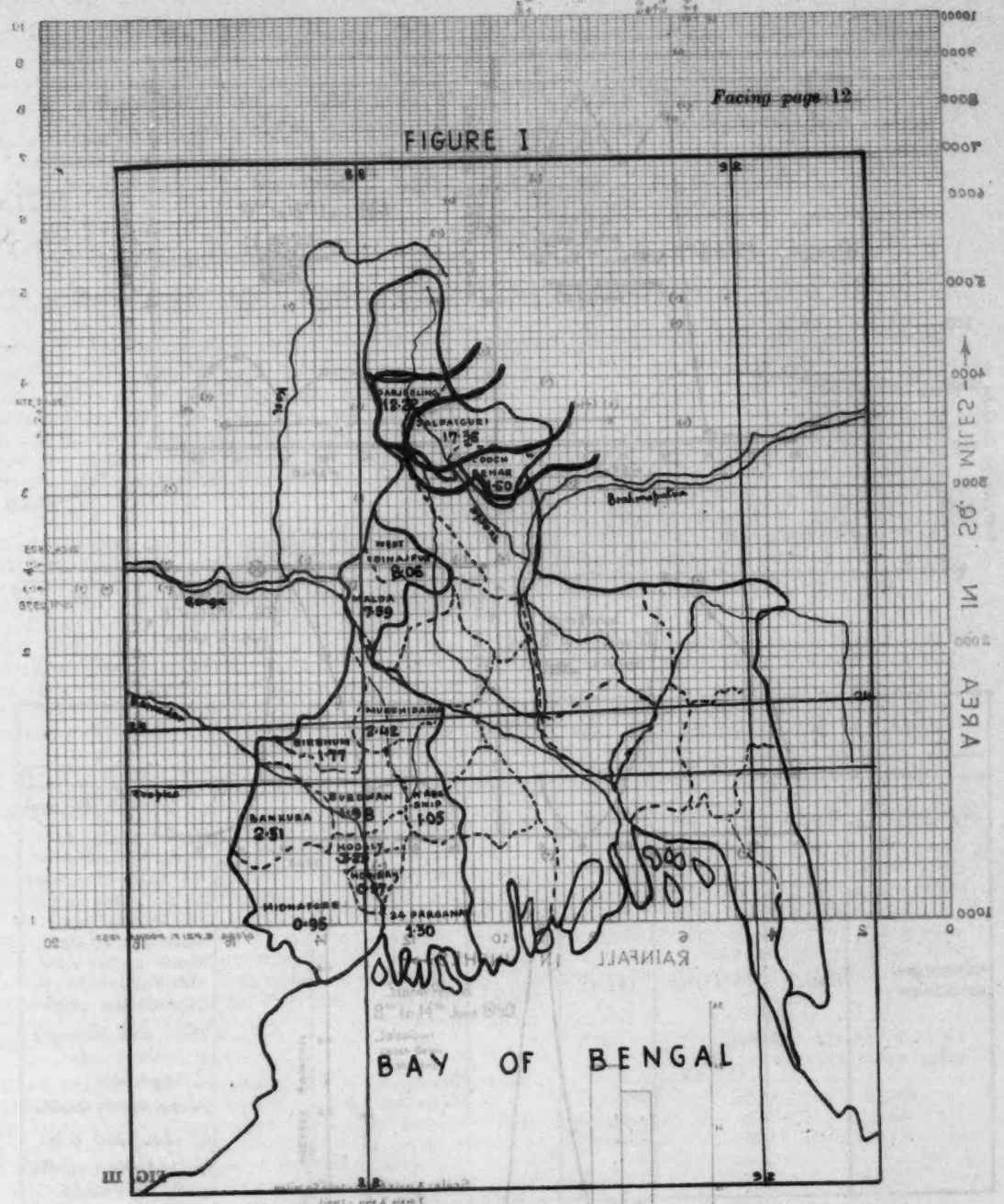
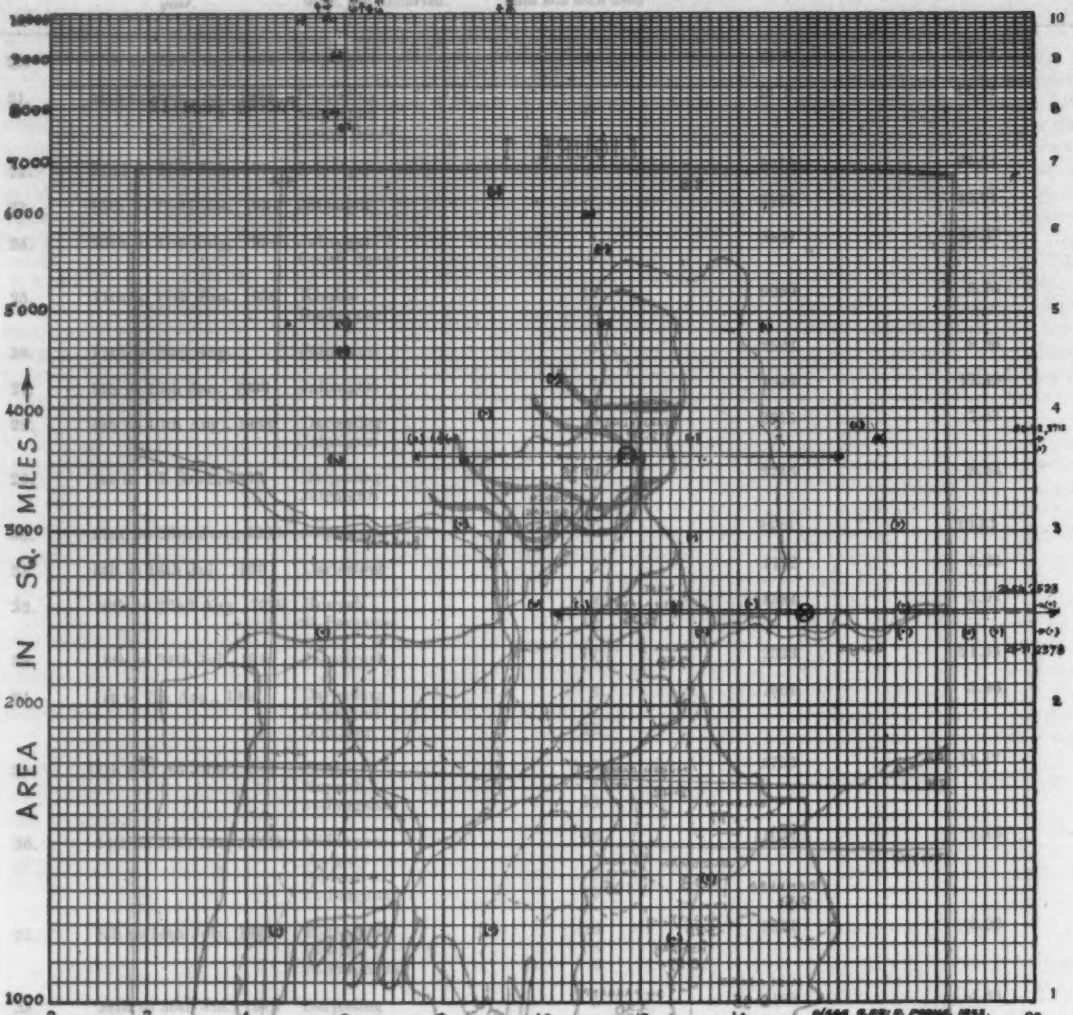


FIG. II—Average Depth Area Diagram



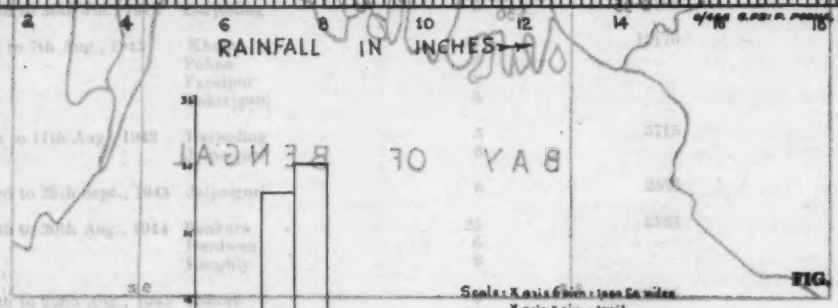


FIG. III

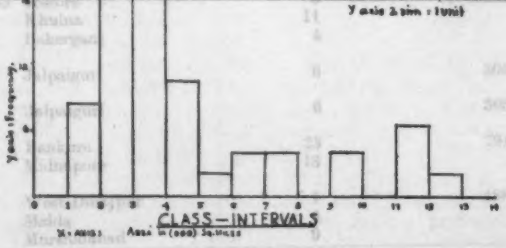


FIG IV
West - Bengal

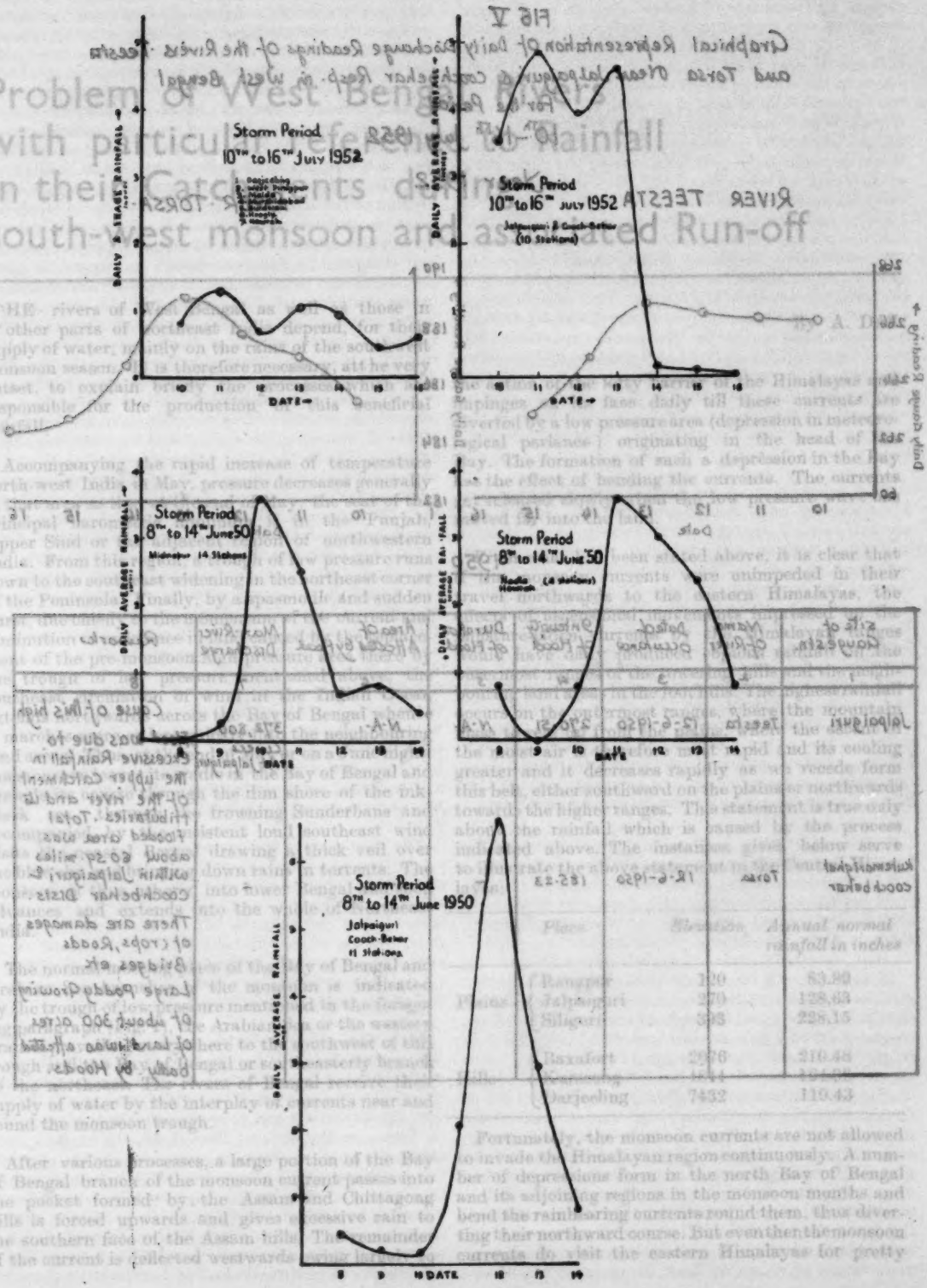
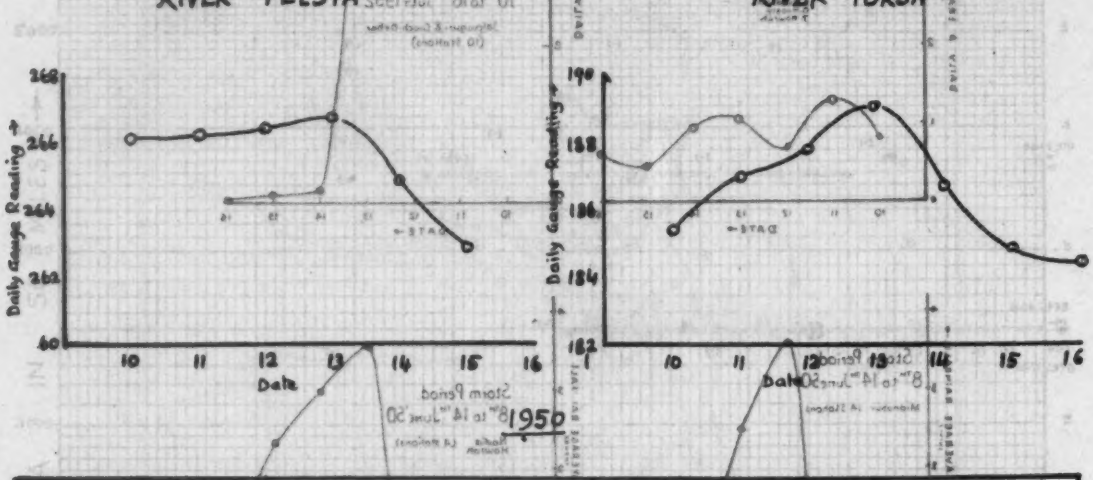


FIG V

Graphical Representation of Daily Discharge Readings of the Rivers Teesta and Torsa Near Jalpaiguri & Coochbehar Resp. in West Bengal For the Period 10th–16th July 1952

Year 1952



1950

Site of Gauge stn.	Name of River	Date of occurance	Intensity of Flood	Duration of Flood	Area of Affected by Flood	Max. River Discharge	Remarks
1	2	3	4	5	6	7	8
Jalpaiguri	Teesta	12-6-1950	270.51	N.A.	N.A.	372,800 Cusecs At Jalpaiguri	Cause of this high Flood was due to Excessive Rainfall in the upper catchment of the river and its tributaries. Total Flooded area was about 60 sq. miles within Jalpaiguri & Coochbehar Dists. There are damages of crops, Roads Bridges etc Large Paddy Growing of about 300 acres of Land was affected badly by Floods.
kulamarighat coochbehar	Torsa	12-6-1950	185.23	—		—	

Problem of West Bengal Rivers with particular reference to Rainfall in their Catchments during south-west monsoon and associated Run-off

By A. DAS

THE rivers of West Bengal as well as those in other parts of northeast India depend, for their supply of water, mainly on the rains of the southwest monsoon season. It is therefore necessary, att he very outset, to explain briefly the processes which are responsible for the production of this beneficial rainfall.

Accompanying the rapid increase of temperature north-west India in May, pressure decreases generally in that area so that at the end of May, the seat of the principal barometric minimum is in the Punjab, Upper Sind or the adjacent region of northwestern India. From this region, a trough of low pressure runs down to the southeast widening in the northeast corner of the Peninsula. Finally, by a spasmodic and sudden burst, due chiefly to the momentum of the current and diminution of resistence in land caused by the replacement of the pre-monsoon high pressure area there by the trough of low pressure mentioned above, the southeast circulation of wind in the Indian Ocean extends northwards across the Bay of Bengal whence it marches more or less quickly into the neighbouring land areas. Thus, at the end of May or on a June night, the monsoon leaves its cradle in the Bay of Bengal and threads its course through the dim shore of the ink-black sea, through the frowning Sunderbans and accompanied by the insistent loud southeast wind visits the coastal Bengal drawing a thick veil over the blue sky and bringing down rains in torrents. The monsoon is thus ushered into lower Bengal and soon advances and extends into the whole of Northeast India.

The normal meeting place of the Bay of Bengal and Arabian Sea branches of the monsoon is indicated by the trough of low pressure mentioned in the foregoing paragraph (Fig. 1), the Arabian Sea or the western branch prevailing everywhere to the southwest of this trough and the Bay of Bengal or southeasterly branch to the northeast. The rivers of Bengal receive their supply of water by the interplay of currents near and round the monsoon trough.

After various processes, a large portion of the Bay of Bengal branch of the monsoon current passes into the pocket formed by the Assam and Chittagong hills is forced upwards and gives excessive rain to the southern face of the Assam hills. The remainder of the current is deflected westwards owing largely to the action of the lofty barrier of the Himalayas and impinges on its face daily till these currents are diverted by a low pressure area (depression in meteorological parlance) originating in the head of the Bay. The formation of such a depression in the Bay has the effect of bending the currents. The currents get released slowly when the low pressure wave has moved far into the land.

From what has been stated above, it is clear that if the monsoon currents were unimpeded in their travel northwards to the eastern Himalayas, the effects of ascensional movements impressed on the moisture-laden currents by the Himalayan ranges would have daily produced copious rainfall on the outermost ranges of the towering hills and the neighbouring land areas in the foot hills. The highest rainfall occurs on the outermost ranges, where the mountain mass towers up from the plains, where the ascent of the moist air is therefore most rapid and its cooling greater and it decreases rapidly as we recede form this belt, either southward on the plains or northwards towards the higher ranges. This statement is true only about the rainfall which is caused by the process indicated above. The instances given below serve to illustrate the above statement in the Central Himalayas:-

	Place	*Elevation*	*Annual normal rainfall in inches*
Plains	Rangpur	120	83.89
	Jalpaiguri	270	128.63
	Siliguri	393	228.15
Hills	Baxafort	2076	210.48
	Kurseong	4844	124.96
	Darjeeling	7432	119.43

Fortunately, the monsoon currents are not allowed to invade the Himalayan region continuously. A number of depressions form in the north Bay of Bengal and its adjoining regions in the monsoon months and bend the rainbearing currents round them, thus diverting their northward course. But even then the monsoon currents do visit the eastern Himalayas for pretty

long spells and that is why the normal monsoon rainfall in the districts of Darjeeling, Jalpaiguri and Cochbehar in North Bengal far exceeds the normal in any other part of West Bengal, Bihar and Assam excluding certain hilly districts of Assam. Though the rivers of Bengal receive their supply of rainfall by the interplay of currents around the monsoon trough which often changes its seat from the normal position and shifts either to the north or to the south of its usual position, the heaviest falls of rain in central and southern districts of West Bengal are generally those which accompany the passage of depressions through or near them. When depressions do not form during the early parts of monsoon or when they are very few during the early monsoon months and short-lived as in the year 1954 for instance, there is deficiency of rainfall in these districts during these months with copious rainfall and consequent floods in North Bengal from the unimpeded monsoon curents making daily journeys towards the eastern Himalayas. The compensating rainfall during the latter part of the monsoon, though makes good the normal for the season, tends to disturb the normal rainfall pattern and consequent even dirtribution in the supply of water to the West Bengal rivers, and their catchment areas so that during one part of the monsoon there is little rain in the rivers while during the other part there is more than than what is wanted.

5. A table showing the normal rainfall during the 4 monsoon months June-September and the normal annual rainfall for the various districts of Bengal and Bihar is given in the attached statement. It will be seen that roughly 75% of the rainfall is recorded during the monsoon months. Though the rainfall for the districts of Nadia, Murshidabad, Birbhum and Bankura is slightly less than the amount required for agricultural purposes, the monsoon rainfall is much more than adequate in the northern districts and more or less sufficient in the region comprising of the central and southern districts of the State. Consequently when the rainfall more or less follows the normal pattern, the rivers passing through these districts receive rainfall sufficient to maintain themselves during the monsoon months and serve the needs of the State as regards agriculture, irrigation and navigation.

6. We are now in a position to study the river problems of Bengal with particular reference to the rainfall in their catchment areas and associated run-off. But, before we proceed to this task, we should be able to understand the particular river problems of Bengal. These are briefly stated below.

In order that a river may sustain itself efficiently, it is necessary that a certain mimimum amount of flow should be maintained throughout the year. The water to maintain this flow is mainly derived from rainfall in the catchment basin though in the case of some rivers some amount is also obtained particularly during the summer months from the melting of snow far away on the mountains in the uppermost catchments of the rivers. The main bulk of water however comes from the precipitation during the four monsoon months June-September. During these four months, we can expect a certain amount of average rainfall—which we call normal rainfall for the four months and the departure from this normal rainfall so far as northeast India as a whole is concerned or even the catchment areas of rivers in West Bengal and its adjoining are concerned, is not large. We therefore know roughly what the yield is likely to be during the four most-productive months. But, the difficulty arises from the fact that neither the distribution over the area nor the amount of precipitation from day to day and month to month tend to be, even generally speaking, uniform. There are periods of heavy downpour followed by days of more or less dry weather. If therefore, most of the rainfall was allowed to flow off as surface run-off, there will be floods following heavy downpour and during the non-monsoon months, when there is very little rain, there will not be sufficient flow in the river channels to sustain animal and plant life. Here nature comes to the rescue. A considerable portion of the monsoon rainfall is used up to replenish what is generally known as 'underground waters' from which is derived the perennial supply of springs and streams. In flat catchments in Bengal, a good amount of the precipitation is absorbed and stored as 'underground water'. In the steepy hill catchments, however, which contributes the major portion of the river flow as the rainfall is much heavier there (vide rainfall table), the surface run-off, because of the gradient, will be much more and consequently the storage will be much less unless the catchment area is covered with thick growth of vegetation which will have the effect of retarding the run-off and by its sponge-like action will absorb a good amount of rainfall which will ultimately be stored as under-ground water. Such vegetation, by minimising run-off will also have the effect of moderating floods. With the pressure of population and the penetration of civilisation into the far-off hilly tracts in the upper catchments of the rivers, it has been found no longer possible to maintain the forests in their virgin conditions. Consequently, as an effect of progressive deforestation, there has been increased run-off with the consequence that absorption of water in the soil is also gradually diminishing. The present noticeable decrease in the dry weather flow of the West Bengal rivers is presumably largely due to the shortage of underground water, which, as stated above, is the main source of river flow in the dry season. The problem therefore is how to keep the rivers in good regime by maintaining a substantial dry weather flow which will also offer all-the-year-round irrigation facilities.

The reduction of the dry weather flow is giving rise to serious problems because it is not only making all-the-year-round irrigation difficult but is adversely affecting navigation and, which is probably more serious in a deltaic area like Bengal, causing rapid deterioration of the tidal channels by non-removal of silts and consequent deterioration of the river-bed—copious supply of dry weather flow being essential for the preservation of these tidal channels.

Rivers should be able to carry certain portion of silt during floods being picked up along with the surface run-off from their catchment basins as without the silt the delta cannot be formed and raised. Incidentally as the silt has good manurial properties such as Nitrogen, Potash and Phosphate, the land is also fertilised when the silt is spilled on banks during floods. Rivers coming down the hill slopes and flowing through non-deltaic region, haye usually got sufficient velocity, because of the gradient, to be able to carry the normal silt-charge. While flowing through deltaic region, with flatter gradient, the velocity is not sufficient to carry the entire silt-load and ordinarily a portion

of the silt-charge is deposited by the flood water on the banks of the rivers. The comparatively silt-free water flows down the channels during the subsiding stages of the floods and maintain them in efficient condition. But with progressive deforestation and consequent gilt denudation in the catchment bagins, thes gilt-charge of most of the rivers is on the increase (Action is being taken in the Damodar Valley area for afforestation and reducton in silt-charge). Even in non-deltaic area, some of the rivers are unable to carry their increased silt-load which is choking their beds and raising their flood levels. In the deltaic area, navigation even in the Ganges is becoming more and more difficult owing to the formation of extensive shoals.

Moreover, owing to the reduction in the underground water storage and insufficiency of rainfall during non-monsoon months coupled with the fact that the rivers in the western portions of the state rise from small hills without any snow caps and consequently without any additional source of supply of water such as melting of snow during the summer, it is no longer possible to maintain sufficient dry weather flow to push down the salinity which is progressing upwards in the Hooghly river. During the months of March to May when the tides are strong and the discharge from the uplands is meagre, the water supply of Calcutta, drawn from Palta about 16 miles from the city, tends to be brackish. Approximately, 2700 cusecs of fresh water is said to be required to make up for the water which evaporates from the water surface of the river, including its lower tributaries, the Rupnarayan and the Damodar, and push back the salinity of the sea. But the dry weather upland discharge of the river is insufficient and the saline flow is creeping upstream with the gradual fall in the dry weather supply from the upland.

The main crop of the province is rice. The water requirements of the 'Aman' crop which grows in the rains is about 42″ spread over the rainy season as given below:

	1*st* 10 *days*	2*nd* 10 *days*	*Rest of the month*	*Total*
May	—	—	2	2
June	2½	2½	2½	7½
July	4	4	4½	12½
August	4	2	2	8
Sept.	3½	2½	1½	7½
Oct.	1½	1½	1½	4½
				42″

From the rainfall table, it would appear that June-September rainfall is sufficient to meet the requirements of the crop. But, as stated before, though the normal rainfall during these months is likely to be 42″ or more, its actual distribution during the months may not be the same as detailed in the previous table. Consequently, during any 10-day period, when the actual rainfall is short of what is required, arrangements will have to be made for some additional supply of water by irrigation channels by making proper storage arrangement during periods of excessive rainfall.

The problems may be summarised as follows:-

(1) Prevention of catastrophic, severe and moderate floods duriug monsoon months. Slight floods are not only unharmful but are definitely beneficial.

(2) Maintenance of sufficient river flow during the dry months for (a) preservation of tidal channel (b) making navigation and irrigation possible (c) for supply of sufficient drinking water and (d) to have proper flushing so as to keep the river channels in efficient condition.

(3) To have sufficient supply of upland water during the months March-May when tides are strong to push down the salt water limit which is tending to advance up the delta.

7. The more important rivers in the western portion of West Bengal are the Rasulpur, the Haldi with the tributaries Kaliaghye and Cossye, Rupnarayan with the tributaries Selye and Darkeswar, the Damodar, the Ajoy and the More-Dwaraka. They rise from the Chotanagpur and Santal Paragana Hills or from hilly tracts in the Midnapore district. The catchment areas of all the rivers are comparatively small varying from 600 sq. miles for Kaliaghye to 8500. sq. miles in the case of Damodar. So, when heavy precipitation is caused by the passage of a depression, the entire catchment area receives heavy rainfall almost simultaneously causing high floods. The floods however are short-lived lasting rarely more than 2 or 3 days. On the other hand, it is quite likely that the entire limited catchment does not receive any rain or receives little rain during comparatively dry spells so that these rivers degenerate into mere trickles some time even during the rainy season, while during the non-monsoon period they are most often practically dry. The reason for such uneven distribution of flow in these rivers is due to the following facts: (1) The catchment areas comprise one of the oldest parts of India and therefore the hills have lost a good portion of their soil cover due to the action of rainfall spread over thousands of years and (2) Extensive deforestation causing further reduction in the underground water storage. Therefore the rivers sometime cause moderate to severe floods during monsoon months due to proportionately larger run-off and consequent defective mechanism of the catchment area for retarding run-off and absorbing and storing rainwater. Moreover, owing to the lack of pressure of sufficient flow from above except during floods, the lower reaches of the rivers usually get choked with tidal silt where the outfalls are tidal as in the case of Damodar. The eastern portion of Burdwan district and the western portion of Hooghly and Howrah districts are said to have been built up by the delta building activity of Damodar while the eastern portion of the Midnapur district appears to heave been built up by Cossye. The average total rainfall in the catchment basins of these rivers during the monsoon months varies from 40 to 45 inches and is usually sufficient for agricultural purposes. This group of rivers constitutes the only source available for water needed for artificial irrigation when, due to errratic distribution of rainfall in any year, it becomes necessary to have artificial aid.

The Mor Irrigation Project for irrigating some tracts of Burdwan and West Murshidabad has been completed. The Damodar Valley Project is also nearing completion and it is hoped that the stored water in the reservoirs will now be able to satisfy agricultural needs and the need for maintaining dry weather flow in the river beds beyond the reservoirs. Along with the construction of the dams, anti-erosion measures by afforestation in the catchment basins are also being taken so that the problems stated in paragraph 7 will progressively decrease so far as these rivers are concerned. The reservoirs will also be able to absorb floods which otherwise may cause damage in the catchment areas in the lower reaches of the river. The other rivers of the group have only very small catchment areas.

8. The main rivers of Central Bengal are (1) Bhagirathi-Hooghly (2) Bhairab-Jalangi (3) Mathabhanga and its branches—Churri and Ichhamati. There are also a large number of tidal creeks south of the above-mentioned rivers. Central Bengal is said to have been built up by the silt carried by the Ganges, which used to flow through Bhairab and Bhagirathi. With the diversion of the Ganges waters through Padma, Bhagirathi now receives only comparatively insignificant quantity of water from the Ganges during floods and has been somehow kept alive by the small rivers which have their outfalls into this river and tidal flushing in its lower reaches. The Bhairab is also almost dead having been cut through first by Jalangi and then by Mathabhanga. Jalangi and Mathabhanga are also unable to draw sufficient waters from the Ganges to be able to spill over the land and to keep their distributaries alive resulting in progressive deterioration of the soil and acute difficulty in drainage and water-logging. Further owing to the lack of supply of sweet water in dry season from above, the salt water limit in their tidal reaches is extending higher and higher up the delta. It is therefore necessary to have some contrivance for drawing from the Ganges a portion of the flood through these rivers for flushing the area. Whether it is possible to introduce supply from the parent source, during the dry season, by a barrage, or by excavating spill channels, it is for the engineers to say. The rainfall in this region is not much slightly less than 40 inches, during the monsoon months. The Northern Bengal however is one of the rainiest regions of India. Day to day rainfall in Darjeeling, Jalpaiguri and Coochbehar districts is many times more heavy than most other places in India. Thus, a rainfall which if husbanded by art could have sufficed for the whole country becomes an agent of destruction by producing floods to a large or small extent every year and runs down to other sources without enriching West Bengal.

9. The main rivers of Northern Bengal are the Teesta and the Mahananda. These channels have catchments of about 6,000 and 10,000 sq. miles of which good portions are in the Himalayas on the north. Although the catchments are small, the snow cap of the Himalayas is believed to furnish a fair amount of steady flow in them.

Extensive cultivation is practised in the mountaineous catchments of these rivers and large scale deforestation has also taken place. A large amount of sand is being washed down from the mountain. This is spoiling the soil fertility of the tracts in the upper reaches. The deforestation has increased the run-off and it has contributed towards an increase—though probably small—in the flood discharges of the rivers.

As I have already explained in paragraph 4, the peculiar meteorological conditions in this part of the country are such that spells of concentrated rainfall in some part or other of the three districts are bound to occur giving rise to floods, small or big. There may also be continuous spells of moderately heavy to heavy rain lasting for many days even when no depression or storm visits this part of the country, the cumulative effect of which is to produce floods. As we know the occurrence of flood in any particular area is determined by the amount of excess of the total inflow of water over the total outflow from the area either by evaporation, soil seepage or by drainage. Rainfall within the region under review and water coming from adjoining area constitute the inflow.

It has been held by some engineers and hydrologists that the rainfall is not the main cause of floods in North Bengal but that deforestation and consequent silt denudation has caused the gradual rise of river beds and consequently with soil conservancy in the hilly region in the upper reaches, a new era of floodless prosperity will be ushered in North Bengal. I wish it were true. The cause of heavy rainrainfall in the submontane districts of West Bengal being what they are, there is always the possibility in monsoon months, of continuous and intense rainfall in, say, Jalpaiguri and Coochbehar districts and consequent floods there. Floods will therefore result irrespective of the quantity of silt though it is quite true that the process will be hastened by the presence of silts and boulders. It is equally true that with the continuous deterioration of the river bed, a stage may be reached when the discharge channel may be so reduced that comparatively less intense rainfall will cause floods. While there is no doubt in my mind that deforestation has been responsible for expediting the process which gives rise to floods and that the relation between precipitation and the highest high water-level in flood will change with afforestation, the high water-level going down to some extent when plenty of trees are grown in the catchment areas, I do not think that it will be safe to put forward the claim that floods in West Bengal will cease with soil conservation. Therefore whenever there has been flood in the region it has invariably been associated with heavy rainfall in excess of the normal rainfall in the area which is also pretty high. One of the dangers only will be overcome with the improvement of the river bed condition. But as nature's law cannot be broken, nor its unwanted bounty controlled, the main cause will still be there.

Unfortunately, it has not been possible to obtain a complete list of all past floods in North Bengal. I had therefore to depend on the data which Professor Mahalanobis compiled many years back and on data of very recent floods. Professor Mahalanobis, came to the conclusion, by analysing data of more than 50 years from 1870-1922, that, rainfall, having regard for its intensity, duration and geographical distribution is the sole cause of occurrence and main-

tenance of floods of whatever magnitude. While, I would not use the word, 'sole cause,' I realise that the Professor used the word as he found that in every case, the rainfall was itself enough, to cause flood which may have been augmented by other reasons also. To those who are interested, I would refer to his most excellent and exhaustive paper.

I have summarised, in appendix 4 (Projection App. 4), the main floods in submontane districts of the present North Bengal, after the partition of the country, during the years 1890-1922 with the reasons causing the floods. I have not reproduced the exhaustive data which have been analysed for this purpose. It will be observed that the flood occurred in Jalpaiguri and Coochbehar districts when the precipitation in these areas have exceeded the normal rainfall by about 100%. But I shall come to that presently.

From a study of a number of important floods, it has been seen that the flood has occurred in Jalpaiguri or Coochbehar districts when the precipitation in these areas have far exceeded the normal rainfall which is quite heavy. Thus, during 1892, the percentage of the normal precipitation which caused flood was 398% in northern parts of Jalpaiguri and Dooars and 478% in southern Jalpaiguri and Cochbehar. Similarly in 1954, when the flood was caused by continuous heavy rainfall over a number of weeks, the actual precipitation week by week in Jalpaiguri and Coochbehar was much in excess of the normal heavy fainfall in these areas (Statement 1(*a*) & 1(*b*), There is therefore reason to believe that floods in northern districts of Bengal are more often caused by local rainfall than by water coming from the adjoining area though it is quite likely that simultaneous heavy rainfall in the Himalayas aggravates these floods though not directly causing them. The possibility of flood occurring comes about when the actual rainfall is in excess over the normal, so that ordinary drainage is unable to carry away the excess amount of water. It is, therefore, not so much the actual rainfall but the excess of the normal which is of importance so far as flood-studies are concerned. From what has been stated above, it will be clear that the construction of retarding basins in mountaineous region or at the foot of mountains will not altogether prevent floods from occurring in the North Bengal districts. Only when there is simultaneous heavy fainfall in the mountains as well as in the sub-mountain districts, the flood from the mountain catchment can be held back while the discharges from the lower reaches are allowed to pass off. Nor will the conservancy of the river in the upper mountain catchment—which is beneficial from other considerations and a move in the right direction—will stop floods in the north Bengal districts. But, one thing is certain, these steps will have the effect of moderating the floods to some extent, the nature and extent depending on whether the severity of the flood has been aggravated largely or only to small extent by the water coming from the adjoining area.

Professor Mahalanobis, by his studies of floods in North Bengal for 50 years, arrived at the following conclusions :—

(1) The frequency of floods of some kind or other is 1 in 2¼ years, of moderate or severe floods 1 in 4 years and of severe floods 1 in 7 years. Catastrophic floods occur about 2 or 3 times in a century.
(2) The observed seasonal variability of rainfall is fairly steady and is of the order of 25 to 30% of the normal precipitation.
(3) The frequency distribution of rainfall is not 'normal', that is, cannot be adequately described by the Gauss-Laplacian law of errors. It is definitely asymetric and the probability of very heavy falls is much greater than given by the simple theory of normal probability.
(4) The available data do not indicate any permanent increase (or decrease) of normal rainfall in North Bengal. (For later figures worked out by me in support see Statement 3).
(5) Sudden and torrential downpours constitute the most important direct cause of floods of North Bengal and have brought about the great floods of North Bengal during the 50 years ending in 1922. (I may add that the same cause has also been responsible for the flood which have since occurred).

As the floods in North Bengal are the most severe in the State as a whole, I have briefly stated some facts regarding the meteorological causes which give rise to these floods. I however do not wish to increase the bulk of the main body of this paper. But I have appended a number of tables and statemens such as Meteorological situations giving rise to floods in North Bengal, weekly statement showing variations from weekly normals when floods occurred and the description of a cyclonic storm which travelled towards eastern Himalays and gave rise to floods by giving concentrated rainfall both in the Himalayas and the sub-mountain districts. I have also given the track the storm. As regards the flood of 1954, I have given a statement showing the rainfall, in excess of normals week by week which was responsible for this flood and other associated data.

10. To revert to the remarks with which I commenced the topic on North Bengal rivers, we have at present been unable to devise ways and means for the proper utilisation of the large volume of water of which Nature has made us a present. Is it possible to make economic storage and expenditure of the copious rainfall by building reservoirs and distributing it during the dry season to meet the various needs of the rivers and the people arising at the time when water supply is scanty ? If this is possible, the water which now goes waste may suffice for the agriculture and industrialisation of a large part of the country. But, that is a problem mainly for the engineers to tackle.

To conclude, the review shows that the rainfall in the different catchments of the West Bengal rivers is sufficient to serve the needs of agriculture and to meet the other requirements. The diminution in the stream flow in the dry weather is due to defective storage of underground water which in the dry season supplies the stream flow rather than deficiency in rainfall. With proper afforestation of the catchment areas, it is possible to retard rapid run-off and to store the necessary underground water to maintain the flow during the dry season. The rainfall, though sufficient during the monsoon, its distribution tends

to be erratic. As at present we are unable to control the rainfall either by making the cloud yield its water-content at a place where there is deficiency of rainfall or divert depressions from a place where Nature's bounty is unwanted, we have to devise ways and means for ensuring sufficient distribution of water in irrigation channels all the year round to suit different crop requirements and maintenance of minimum stream-flow in river channels by constructing reservoirs whenever possible. The schemes for construction of reservoirs, whenever possible as in the case of Damodar and Mor, are therefore steps in the right direction. Such reservoirs will help to control flood and storage of water and its economical expenditure with a view to ensure the above requirements.

For reaching a scientific conclusion it is necessary to compile a list of all the past floods in North Bengal, to classify them according as they are slight, moderate or severe and to correlate them with the available rainfall data. We can then find out the actual excess over normal for the entire region or a part of the region which causes flood and what excess in that region will cause flood of how much intensity. The problem is however complicated with the actual period of occurrence of heavy rain. Once we are able to make an accurate estimate of the above factors, we shall be able to form an idea of the extent of improvement in the river regime achieved by the steps we take by conducting a study of a particular weather situation with a similar situation in the past. As regards floods, Professor Mahalanobis has stated that much could be done by the issue of timely warnings for mitigating the evils caused by floods. The prediction of floods or operation of reservoirs if such reservoirs are constructed can be attempted on (*a*) the weather chart (*b*) the records of rainfall in the river basins and (*c*) the actual rise of streams in the upper reaches.

(*Statements and Appendices printed separately*)

Continued from page 20

Principal Meteorological Conditions in relation to the Floods of West Bengal Rivers

relation to significant pressure systems and fronts on the synoptic charts and tracing their movements.

(2) Drawing depth-duration-area curves of precipitation over the area affected by the significant pressure systems and fronts and determination of the ratio of peak precipitation to the average precipitation over that area.

(3) Study of the life history of significant pressure system and fronts and of the existing synoptic situation with a view to finding out their anticipated development and movement.

(4) Estimating the shift of precipitation and its intensity with reference to the anticipated development and movement of the significant pressure systems and fronts as indicated in (3) above.

(5) On the basis of 2, 3 and 4 above, drawing prognostic depth-duration-area curves of precipitation for the areas concerned in respect of a subsequent period of say 24 hours for the purpose of estimating the total volume of precipitation and the peak precipitation for different areas for that period.

An alternative method of approaching the problem of quantitative estimation of precipitation is to draw percentage depth anomaly duration-area curves instead of depth-duration-area curves. Acceptance of percentage departure from daily normal instead of actual rainfall will tend to wipe out the irregularities in the depth-duration-area curves on account of the unusally large or small values of precipitation characteristic to some stations on account of local peculiarities. This is, however, subject to the availability of daily normal rainfall for all the stations concerned calculated on the basis of data for a large number of years.

From the above analysis the total volume of rainfall over the sources and catchments of a river for a few consecutive days, including the period to be covered by the forecast can be estimated. A comparison of the rainfall volume thus estimated with the volume calculated from actual data for a corresponding period and month when flood occurred in the river concerned in past years may be helpful in the forecasting of flood sufficiently in advance.

TABLE 2

Noteworthy daily rainfall during the period 21-8-54 to 25-8-54.

Rainfall in inches—August, 1954.

	21	22	23	24	25	
Katmandu	—	—	2	2	3	
Dolalghat	2	2	2	2	2	
Dhulikhel	—	—	2	4	4	
Machuaghat	—	—	—	5	2	
Phalut	—	—	2	4	2	
Tribeni	—	2	—	5	—	
Borahakshetra	—	3	3	5	2	
Kalimpong	—	—	—	4	—	
Jalpaiguri	—	—	2	*	*	*No record due to flood
Shillong	—	2	3	—	—	
Cherrapunji	6	13	21	12	2	
Dhubri	2	—	—	—	—	
Tura	—	5	—	—	—	

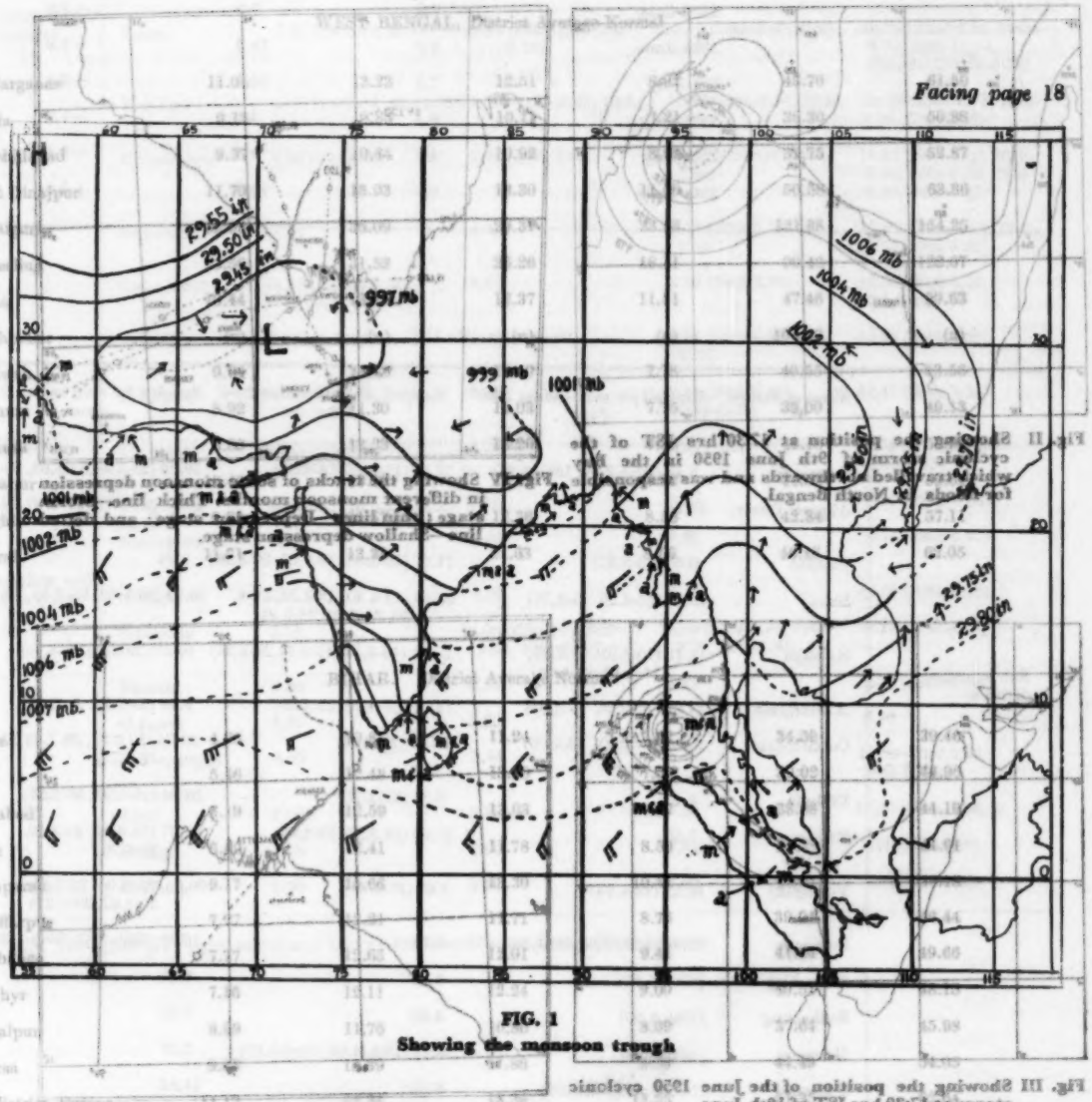


FIG. 1
Showing the monsoon trough

Facing page 18

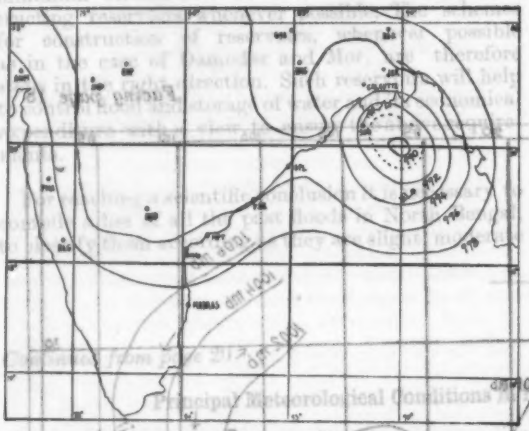


Fig. II Showing the position at 17·30 hrs IST of the cyclonic storm of 9th June 1950 in the Bay which travelled northwards and was responsible for floods in North Bengal.

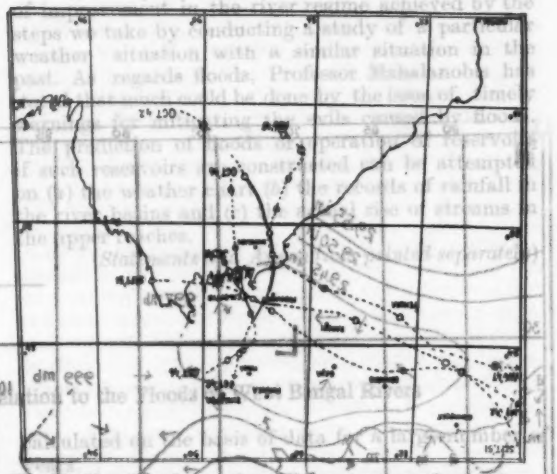


Fig. IV Showing the tracks of some monsoon depression in different monsoon months. Thick line—storm stage ; thin lines—Depression stage : and dotted line—Shallow depression stage.

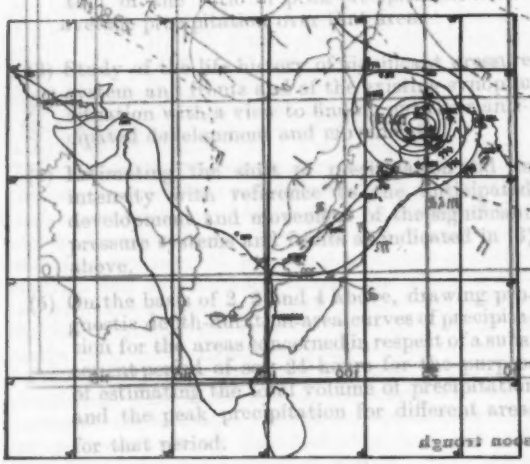


Fig. III Showing the position of the June 1950 cyclonic storm at 17·30 hrs IST of 10th June

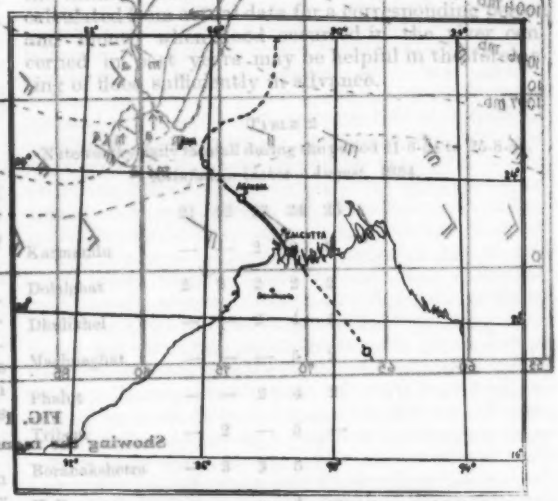


Fig. V Showing the track followed by the cyclonic storm of June 1950. Thick line shows storm stage, thin line shows depression stage and dotted line shows shallow depression.

Statement I

	June	*July*	*August*	*September*	*Total*	*Annual Normal Average*
WEST BENGAL. District Average Normal						
24-Parganas	**11.04**	**13.23**	**12.51**	**8.92**	**45.70**	**61.59**
Nadia	**9.13**	**9.85**	**10.11**	**7.21**	**36.30**	**50.88**
Murshidabad	**9.37**	**10.84**	**10.92**	**8.62**	**39.75**	**52.87**
West Dinajpur	**11.70**	**13.93**	**13.30**	**11.56**	**50.58**	**63.86**
Jalpaiguri	**32.99**	**36.09**	**29.37**	**23.43**	**121.88**	**154.25**
Darjeeling	**23.56**	**31.53**	**26.26**	**18.11**	**99.46**	**122.67**
Malda	**10.44**	**13.14**	**12.37**	**11.51**	**47.46**	**59.63**
Coochbehar	**(n)**	**(n)**	**(n)**	**(n)**	**106.40**	**(n)**
Burdwan	**9.94**	**11.43**	**11.40**	**7.78**	**40.55**	**59.56**
Birbhum	**8.92**	**11.30**	**11.03**	**7.75**	**39.00**	**49.13**
Bankura	**8.80**	**12.23**	**12.20**	**6.95**	**40.18**	**50.95**
Midnapur	**10.40**	**13.09**	**12.72**	**8.32**	**44.53**	**59.61**
Hooghly	**9.88**	**11.57**	**12.36**	**8.53**	**42.34**	**57.11**
Howrah	**11.71**	**13.28**	**21.63**	**8.56**	**46.18**	**62.05**
BIHAR. District Average Normal						
Patna	**4.98**	**10.61**	**11.24**	**7.47**	**34.30**	**39.46**
Gaya	**5.46**	**12.48**	**13.50**	**7.58**	**39.02**	**44.96**
Shahabad	**5.19**	**12.59**	**13.03**	**7.87**	**38.68**	**44.19**
Saran	**6.59**	**12.41**	**11.78**	**8.50**	**39.28**	**44.91**
Champaran	**9.17**	**15.66**	**13.30**	**10.41**	**48.54**	**56.18**
Mazaffarpur	**7.27**	**12.21**	**11.71**	**8.75**	**39.94**	**46.44**
Darbhanga	**7.77**	**12.65**	**12.01**	**9.41**	**41.84**	**49.66**
Monghyr	**7.16**	**12.11**	**12.24**	**9.00**	**40.51**	**48.15**
Bhagalpur	**6.99**	**11.76**	**10.80**	**8.09**	**37.64**	**45.98**
Saharsa	**9.25**	**13.39**	**11.86**	**9.99**	**44.49**	**54.05**
Sub-district Purnea	**11.12**	**15.34**	**13.36**	**11.53**	**51.35**	**62.64**
Santal Pargana	**9.05**	**12.77**	**12.16**	**9.74**	**43.72**	**54.20**
Hazaribagh	**6.94**	**13.05**	**13.01**	**8.25**	**41.25**	**49.55**
Ranchi	**7.98**	**15.68**	**14.99**	**8.52**	**47.17**	**57.61**
Palamau	**6.55**	**14.69**	**15.10**	**7.87**	**44.21**	**51.62**
Manbhum	**8.25**	**13.04**	**12.84**	**8.02**	**42.15**	**52.90**
Singhbhum	**9.51**	**13.69**	**13.84**	**7.97**	**45.01**	**56.43**

Statement 1A

Statement showing the continuous rainfall of Sub-Himalayan West Bengal in excess of the normal which was responsible for the 1954 floods

Year	*Week ending*	*Normal for the week*	*Actual for the week*	*Excess (+) Deficit (—)*
1954	16th June	5.2	6.9	+1.7
,,	23rd June	6.0	9.0	+3.0
,,	30th June	6.3	15.2	+8.9
,,	7th July	7.2	10.3	+3.1
,,	14th July	6.5	4.8	—1.7
,,	21st July	4.8	9.3	+4.5
,,	28th July	4.5	10.3	+5.8

Statement No 1(b)

	Name of Station	*Rainfall for week ending 16th June*	*Rainfall for week ending 23rd June*	*Rainfall for week ending 30th June*
Sub-montane districts	Jalpaiguri	5.17 (10th-3.90, 13th-3.25)	13.13 (17-3.14, 18-4.28)	19.75 (28-3.21,29-5.68, 30-6.80)
	Alipore Duars	12.10	13.37 (17-4.62, 18-2.70)	26.77 (27-7.75, 28-4.10, 29-10.25)
	Falkata	9.56 (12-3.32)	17.37 (18-3.08, 19-3.67, 20-5.25)	9.94
	Buxa	13.42 (11-4.50, 13-3.75)	29.60 (17-6.20, 18-4.55, 19-8.20, 21-3.75, 22-5.25)	20.74 (28-5.82, 29-6.35, 30-3.81)
	Kalchini	19.19 (10-2.91, 12-5.29, 14-3.42, 15-4.64)	27.31 (18-6.54, 19-8.71,23-3.24)	10.27 (29-3.37,30-3.16)
	Kumargram	11.95 (12-3.20, 13-3.00)	14.50 (20-3.00, 23-3.20)	9.45 (29-3.30, 30-3.15)
	Coochbehar	12.08 (11-3.83, 16-4.00)	13.05 (20-6.63)	26.54 (27-3.67, 28-7.63,29-7.85, 30-4.71)
	Dinhata	8.43	8.94 (21-3.73)	16.84 (29-9.45, 30-3.31)
	Mekliganj	7.55	12.06 (18-5.20, 19-4.03)	19.57 (28-6.45, 29-3.06, 30-6.70)
	Tufanganj	16.25 (15-4.04)	7.63 (20-3.50)	20.64 (25-2.90, 28-3.41, 29-3.62, 30-7.70)
	Bagdogra	12.94 (12th-5.28, 15-5.30)	8.81	12.29 (26th-3.25, 30th-5.33)
Darjeeling and Sikkim hill area	Darjeeling	(15th-6.82)	6.86	6.48
	Kalimpong	(15th-3.95)	8.69	7.13
	Mongpoo	(15th-8.71)	13.47 (18th-4.08, 23rd-5.06)	7.87
	Kurseong	(14th-4.10,15th-5.00)	6.95	11.52
	Namchi	7.72 (15th-4.03)	6.94	5.12
	Gangtok	14.35 (15th-3.08)	4.40	6.65
	Pemayangsi	11.07 (15th-4.59)	8.17	7.11
	Temi	13.13 (15th-4.59)	5.93	5.33
	Rangpo	5.33	4.43	3.58
	Chakeng	9.75 (15th-4.50)	7.01	4.45

P.S. The figures in ( ) give amounts of heavy rainfall on dates against which these figures have been indicated.

Statement No 2

Statement showing the rainfall recorded in different stations of sub-montane districts of North Bengal and the Darjeeling and Sikkim hills during July, 1954, week by week.

	Name of station	Week ending 7th July	Week ending 14th July	Week ending 21st July	Week ending 28th July
Sub-montane districts	Jalpaiguri	11.78 (1st-2.75, 4th-5.58)	9.28 (10th-3.35, 12th-3.85)	17.35 (17th-4.84, 19th-3.37, 20-3.70)	14.71 (24 th-2.93, 25th-8.35)
	Alipore Duars	6.20 (2nd-3.10)	6.63 (9th-3.95)	20.20 (18th-3.10, 19th-8.60, 20th-5.15)	30.15 (23rd-4.25, 24th-14.90, 25th-5.20)
	Buxa	7.90 (1st-2.80, 3rd-3.80)	16.93 (9th-7.20, 12th-3.70)	15.15 (16th-5.40, 19th-5.00)	40.36 (22nd-4.69, 24th-6.37, 25th-11.76, 26th-6.14, 27th-8.74)
	Kalchini	9.99 (1st-3.17, 4th-4.53)	14.87 (10th-5.67, 13th-5.24)	11.46 (19th-3.14, 20th-5.46)	24.86 (25th-6.72, 26th-9.94, 27th-3.38)
	Kumargram	4.80 (1st-3.16)	8.50 (12th-2.98)	9.30 (19th-4.00,20th-3.20)	18.47 (24th-3.20, 25th-3.46, 26th-3.50, 27th-2.90, 28th-3-19)
	Bagdogra	2.75	4.99	9.48 (19th-2.78, 20th-3.00	18.82 (25th-5.30, 26th-4.33, 28th-4.92)
	Coochbehar	18.33 (1st-6.75, 3rd-10.20)	3.04	8.44 (18th-2.91)	15.93 (23rd-3.15, 25th-6.44)
	Dinahata	6.54 (3rd-3.50)	0.42	11.22 (18th-4.30, 21st-3.35)	12.06 (25th-7.02)
	Mekliganj	13.36 (1st-3.90, 3rd-5.67)	0.67	13.55 (19th-3.30, 20th-3.30)	11.47 (25th-3.35)
	Tufanganj	20.40 (1st-8.05, 3rd-9.10)	2.76	11.23 (19th-5.52)	16.56 (25th-8.10, 26th-3.25)
Darjeeling and Sikkim Hills	Darjeeling	3.19	3.94	5.48	6.59 (28th-4.16)
	Kalimpong	3.15	6.40	3.61	9.73 (28th-6.97)
	Mongpoo	5.18	8.66	5.51	10.30 (28th-6.16)
	Kurseong	3.75	15.06 (8th-3.00, 9th-2.80, 10th-5.40)	14.15 (17th-3.00, 19th-3.75, 21st-3.30)	10.21 (27th-4.25)
	Namchi	2.60	3.52	4.42	9.29 (28th-5.76)
	Gangtok	2.55	5.20	7.25	6.70
	Pemayangtsi	4.47	3.44	8.07	12.90 (23rd-3.86, 28th-2.88)
	Temi	2.06	2.35	7.58	11.10 (28th-6.40)
	Rongpo	1.76	2.54	3.04	4.00(28th-2.70)
	Chakung	2.60	3.90	3.93	7.80(28th-4.22)

P.S. The figures in ( ) give amounts of heavy rainfall on different dates indicated therein

Statement 3

Statement showing departure of total rainfall for June to September from normal in North Bengal districts during the 20 years from 1935 to 1954 showing no trend towards increase or decrease from normal.

S. No.	Normal rainfall years	Jalpaiguri	Darjeeling	Coochbehar	Remarks
	Normal rainfall	**121.88**	**99.46**	**97.45**	
1.	1935	**+11.62**	**+1.27**	**+17.30**	
2.	1936	**— 4.26**	**— 0.38**	**— 8.13**	
3.	1937	**—27.80**	**—15.29**	**—25.03**	
4.	1938	**+31.21**	**+14.67**	**+ 4.38**	
5.	1939	**+ 0.17**	**— 7.40**	**—14.34**	
6.	1940	**— 4.75**	**—11.04**	**— 8.36**	
7.	1941	**+ 4.03**	**— 9.45**	**+13.38**	
8.	1942	**—34.91**	**— 6.76**	**—28.93**	
9.	1943	**+17.75**	**— 7.32**	**+19.37**	
10.	1944	**— 2.12**	**—14.12**	**— 2.14**	
11.	1945	**+ 1.19**	**+ 1.85**	**— 9.40**	
12.	1946	**—14.59**	**— 2.36**	**—24.74**	
13.	1947	**—15.98**	**— 6.16**	**—23.84**	
14.	1948	**+ 6.45**	**— 5.29**	**— 2.73**	
15.	1949	**— 2.44**	**+17.39**	*	* Data not available
16.	1950	**— 4.07**	**+32.68**	**— 6.09**	
17.	1951	**+ 7.52**	**+16.88**	**— 1.08**	
18.	1952	**— 2.90**	**+19.72**	**—25.15**	
19.	1953	**—33.71**	**+ 2.27**	**—12.15**	
20.	1954	**+37.66**	**+ 0.22**	**+11.35**	

N. B. Figures underlined are extreme deviations.

Statement 4

Statement showing the damages caused on different dates by flood in North Bengal during June and July, 1954.

15-6-54	**Siliguri-Kalimpong road blocked**	**2-7-54**	**Coochbehar town under flood water**
16-6-54	**Kalimpong cut off by land slides**	**21-7-54**	**40,000 areas swamped by Teesta floods.**
20-6-54	**Heavy damage by Teesta floods, 30,000 area of land inundated**	**28-7-54**	**Situation takes serious turn in Cochbehar**
		29-7-54	**Coochbehar floods.**
27-6-54	**Jalpaiguri Union still under water**	**30-7-54**	**Worse than in 1952.**
1-7-54	**Darjeeling cut off from Siliguri**	**1-8-54**	**Coochbehar flood water receding.**

Appendix I

Meteorological situations giving rise to floods in North Bengal

(1) Cyclonic storms originating in the Bay of Bengal and travelling in a northerly or northeasterly direction and ultimately bursting upon the eastern Himalayas.

(2) Non-formation of depressions for long periods and consequent non-diversion of monsoon-bearing currents from their daily journeys northwards towards the eastern Himalays.

(3) Monsoon becoming weak and causing northward displacement of the axis of low pressure trough of northern India to the foothill of the Himalayas and causing the Arabian Sea branch of the monsoon to penetrate into the eastern Himalayas. The position may be further aggravated by simultaneous eastwards passage of depressions from the northwest of India through the periphery of the Himalayas.

Situation number (1) causes torrential rainfall both in the Himalayas and sub-montane districts of North Bengal but the Darjeeling district (including adjoining hills) is generally more affected.

Recent example—The flood of June 1950.

A cyclonic storm which was formed in the Bay of of Bengal on the 9th of June, crossed coast on the afternoon of 10th. Thereafter, it travelled northwards ultimately breaking up in the neighbourhood of Darjeeling hills (vide storm track and weather charts showing the position of the storm on the 9th and 10th June, 1950). It gave very heavy rainfall in North Bengal and eastern Himalayas. The rainfall recorded on the 11th, 12th and 13th are indicated below:—

It will be observed that the rainfall was extraordinarily heavy in the Darjeeling district and towns in the foothills. As is well known, Darjeeling was cut off completely from the rest of West Bengal and the Teesta Valley railway lines in the district were washed off.

Situation (2) and (3) generally causes floods in the sub-montane districts of North Bengal as the floods are due to the cumulative effect of moderately heavy or heavy falls over a fairly long period and the rain from the hill catchments where the falls are not very concentrated can be easily drained off due to gradient in the catchment area. Floods occur only when the rainfall is in excess of the normal rainfall. If the excess is very large, even a short-period of excessive rainfall can give floods. But, in such cases, the flood is short-lived unless maintained by subsequent excessive rainfall. On the other hand, when the excess over normal (which in North Bengal is pretty high) continues for a long time, the flood also persists. Recent example : The flood during June, July and August, 1954. The cumulative rainfall graphs of Cooch Behar, Jalpaiguri and Bagdogra show that right from the 10th June, there has been continuous rise in graphs throughout June and July far exceeding in steepness either the normal rainfall graph or the rainfall graphs of any of the three preceeding years 1951, 1952 and 1953.

The rainfall tables in the enclosed statements No. 1 (*b*)-2 are interesting.

Though, there were land-slides in the Darjeeling district in the week ending 16th June, the floods actually started early next week. It will be evident from the rainfall statement that the flood was actually started and maintained by the concentrated falls mainly in the sub-montane districts. It is true that

		11th	12th		13th Rain gauge under water	
North Bengal including Darjeeling	Jalpaiguri	0.28	11.24			
	Alipore Duars	2.32	6.74		2.2	
	Falkata	5.60	1.50		Nil	
	Buxa	5.50	12.90	(July)	9.30	
	Kalchini	0.52	4.49		4.26	
	Kumargram	4.50	0.73		Nil	
	Siliguri	3.50	6.95		6.60	
	Darjeeling	4.17	17.88	(July)	10.16	
	Kalimpong	1.19	11.89	(September)	11.70	
	Mongpoo	1.35	21.50		15.00	
	Kurseong	19.75	18.27		4.73	
	Cooch Behar	1.00	10.36		7.58	
	Dinhata	0.80	10.58		5.48	
	Mathabhanga	0.78	7.43		1.71	
	Mekliganj	0.70	13.50		4.70	
Sikkim Hills	Namchi	3.43	6.46		9.32	

on one day, namely the 15thJune, there was torrential rain in the Darjeeling and Sikkim hills which must have aggravated the floods. But, during the subsequent two weeks the flood was maintained by exceptionally heavy falls in the sub-montane districts and there was hardly any heavy rainfall either in the Darjeeling or in the Sikkim hills. An analysis of the July rainfall also shows that the continuance of the floods was mainly due to torrential rains in the sub-montane districts, the only hill station where some heavy rains were recorded during the 2nd and 3rd weeks being Kurseong. As regards the fourth week, very heavy falls (4 to 15 inches) were recorded in the sub-montane districts throughout the week while in the hill stations, heavy falls occurred only one on day. It is therefore abundantly clear that flood was caused mainly by exceptionally heavy showers in the sub-montane districts.

This is also reflected in the flood pattern. Statement 4. An area comprising of 30,000 square miles was reported to have been inundated on 20.6.54 and wide-spread floods both in the districts of Coochbehar and Jalpaiguri continued throughout the months of June and July, the flood water receding only on 1.8.54.

APPENDIX 2

Report of rainfall and floods in North Bengal by P. C. Mahalanobis (1870-1922).

List of floods in North Bengal during 1870-1922

Sl No.	*Year and flood month*	*Rainfall Period*	*Affected area*	*Intensity of floods*	*Extent of Damage*	*Remarks*
1	2	3	4	5	6	7
1.	1870 (July & Aug)	July & Aug.	Rajshahi & Pabna (B-2, B-3)	(c) Moderate.	Great Damage to crops.	Overflow of the Ganges. High level of the Brahmaputra.
2.	1871 (End of Aug. to second week of September)	September	Malda & Rajshahi (Lower part) B-2, B-3, C-1, C-2	(b) Severe & extensive.	Considerable loss of cattle.	Excess rainfall. Exceptionally high level of rainfall.
3.	1874 (September)	29th Aug. to 15th September	Rajshahi & Pabna (B-2)	(c) Moderate	Great damage to crops.	High level of the G. & of the B. Local excess of rainfall.
4.	1875 (August)	..	Pabna	(d) Slight.	Damage to crops	High level of the Ganges. Heavy local falls.
5.	1879 (August)		Rajshahi	(d) -do-	-do-	High level of the Ganges caused by heavy falls in the U. P. & Bihar.
6.	1885 (September)	Aug. & Sept.	Rajshahi, Malda & Dinajpur. (C_1, B_1, & B_4)	(b) Severe	Considerable loss of hyuman life & cattle destruction of property.	Heavy local falls. Very high level of the Ganges.
7.	1886 (September)	6th to 11th September	Bogra, Malda, Rajshahi & Pabna. (B_3, B_4, & C_3)	(c) Moderate	Destruction of houses & property	Excess rainfall. High level of the Gauges and the Brahmaputra.
8.	1890 (August)	..	Pabna	(c) Moderate.	Roads seriously damaged.	Overflow of the Gauges
9.	1890 (August)	..	Darjeeling	(d) Slight.	Roads seriously damaged	High level of the Tista
10.	1892 (July)	1st to 8th July	Jalpaiguri, Darjeeling, Rangpur & Dinajpur. A_2, A_3, B_1, C_1&C_2	(b) V. severe	Considerable loss of human life and distruction of cattle; great damage to roads & property.	Very heavy falls. High level of the Tista, Mahanandi, Dhari and Atrai. Serious holding of water in Dinajpur and Rangpur by the railway line.
11.	1892 (July)	-do-	Pabna (B_2)	(d) Slight	..	Overflow of the Ganges.
12.	1898 (September)	..	Darjeeling	(c) Moderate	Damage to crops	Local rainfall.
13.	1899 (September)	September	Darjeeling. (A_1, A_2)	(a) Very severe	Destructive land slips, caused loss of life and unprecedented damage to roads, bridges and buildings.	Very heavy rainfall on the 24th and 25th Sept.
14.	1902 (August)	..	Coochbehar & Rangpur. (B_1, C_2)	(d) Slight	..	Excess of rainfall.

Table continued on next page

1	2	3	4	5	6	7
15.	1902	(September)	September	Jalpaiguri (A_3)	(*b*) Severe	Ten lives lost; damage to railways; serious loss of cattle	Heavy falls in the hills. Overflow of the Tista.
16.	1904	(August)		Malda	(*d*) Slight.		Exceptionally high level of the Gauges.
17.	1906	(Aug. & Sept)	27th July to 5th Aug. 27th July to 20th Aug.	Jalpaiguri Coochbehar and Darjeeling (A_2, A_3 & B_1)	(*b*) Severe	Extensive damage to crops & property	Heavy rainfall
18.	1906	(Aug. & Sept.)	27th July to 5th Aug., 20th July to 20th Aug.	Pabna, Rajshahi & Malda (B_2, B_3 & C_3)	(*d*) Slight	Famine conditions in Malda and Rajshahi	Abnormal rise of the Brahmaputra
19.	1910	(July)	8th to 31st July	Coochbehar and Jalpaiguri (B_1)	(*c*) Moderate	Several breaches in the Rly. lines	Excessive local rainfall
20.	1910	(July)	8th to 31st July	Pabna (B_1)	(*d*) Slight		Abnormaly high. level of the Brahmaputra
21.	1915	(August)	7th to 15th Aug.	Duars (B_1)	(*d*) Slight	Damage to crops	Heavy local rainfall
22.	1915	(First week of September)		Pabna (B_2, B_3)	(*d*) Slight	Villages under water	A high river level
23.	1918	(End of August)	18th to 27th Aug	Rajshahi, Bogra, Dinajpur, Pabna and Malda (C_1, C_2, C_3, B_2 & B_3)	(*b*) Severe	Several deaths and considerable damage to crops & property	Heavy cyclonic rainfall on the 24th, 25th and 26th August
24.	1919	(End of Aug. & First week of September)		Pabna	(*d*) Slight		Overflow from the Ganges
25.	1922	(Last week of Sept. to middle of October)	Week ending 27th Sept.	400 Sq. miles in Bogra, 1200 Sq.-miles in Rajshahi, and a small portion in Pabna & Dinajpur (C_3)	(*a*) Very severe and extensive	Estimated loss of property worth six crores	Exceptionally heavy cyclone clonic precipitation in the week ending 27th Sept.

Appendix 3

North Bengal may be conveniently divided into three distinct natural divisions with three sub-divisions in each:—

(A) Hilly districts and submountain country including

(1) Hilly district of Darjeeling

(2) Sub-mountain country running parallel to the foot hills of Himalayas

(3) South-easterly projection on the west bank of the Tista in the district of Jalpaiguri

(B) The flat riparian tracts drained by the three great rivers of North Bengal comprising:

(1) The north-eastern basin of the Tista

(2) The low-lying country on the right (west) bank of Brahmaputra

(3) The spill area on the left (north) bank of the Ganges

(C) The country in the interior

Flood list for area A_1

1886—September	Darjeeling		(C) Moderate
1890—August	-do-		(C) -do-
1892—July	-do-		(b) Very severe
1898—September	-do-		(C) Moderate
1899— -do-	-do-		(a) Catastrophic
1906—August & September	-do-		(C) Moderate

Flood list for area A_2

1886—September	Jalpaiguri	(d) slight
1892—July	-do-	(b) very severe
1898—September	Dooars	(d) slight
1899— -do-	Jalpaiguri	(b) severe
1906—August & September	-do-	(b) severe

Flood list for A_3		
1892—July	Jalpaiguri	(b) severe
1899—September	-do-	(C) Moderate
1902— -do-	-do-	(b) severe
1906—August & September	Jalpaiguri & Coochbehar	(b) extremely severe
Flood list for B_3		
1890—August	Dooars	(C) Moderate
1892—July	Dooars & Rangpur	(b) severe
1902—August	Coochbehar	(d) slight
1906—August & Septembas	-do-	(b) very severe
1910—July	-do-	(C) Moderate
1915—August	Dooars	(d) slight

The occurrence of a flood in any particular area is determined by the amount of excess of (A) the total inflow of water over (B) the total outflow from that area, either by evaporation, soakage into soil or by drainage.

It scarcely needs mentioning that rainfall, having regard for its intensity, duration and geographic distribution is the sole cause of occurrence and maintenance of floods of whatever magnitude.

Under (A)

(1) Actual rainfall within the area under consideration

(2) Water coming from adjoining areas

Regarding (B)

(1) The portion interrupted by trees, bushes and other obstacles and evaporated before reaching ground.

(2) Evaporation from the surface of the soil

(3) Evaporation from the soil below the surface

(4) Portion replenishing underground storage of water

(5) Surface and sub-surface drainage

(6) Drainage by rivers

(7) Artificial obstruction to drainage such as railway lines, roads or embankments

(8) Sudden and torrential downpours

(9) Long-continued excess of general rainfall is also an important factor.

Appendix 4

Causes of floods in Submontane areas of North Bengal in different years

1890—In portions of the Duars and Coochbehar rainfall was from 30%-50% above normal in July and from 80%-100% above normal in August.

1892—Exceptionally heavy rainfall throughout North Bengal during the 1st week of July. The actual excess during these days was more than 200% over a large area.

1898—Rainfall was generally heavy throughout September. From 1st to 11th September, rainfall in the districts of Jalpaiguri, Rangpur and Coochbehar was over 100% in excess. Taking the whole period 1st to 22nd into consideration, there was excess of more than 100% over the greater part of North Bengal, the excess at Darjeeling being about 200%.

1902—100% excess in Jalpaiguri and Darjeeling districts.

1906—The rainfall in the northern districts of Darjeeling, Jalpaiguri and Coochbehar for the period 27th July to 5th August, shows that the excess was considerably over 200% in the extreme northwest and over 100% through the westeast and southeast portions of North Bengal.

1910—Rainfall was in moderate excess nearly everywhere in North Bengal. The heavy falls were confined almost exclusively to the districts of Coochbehar and Jalpaiguri. In the districts of Jalpaiguri and Coochbehar and Siliguri heavy rain commenced from the 8th and continued almost uninterrupted till the end of the month.

1915—Heavy falls occurred in the Jalpaiguri and Darjeeling districts for about a week from the 7th to the 15th August.

Principal Meteorological Conditions in relation to the Floods of West Bengal Rivers

By K. C. CHAKRAVORTTY

FLOODS occur at times in some rivers of West Bengal and cause considerable damage. In modern times people have learnt not to yield helplessly to these destructive phenomena as God-sent and inevitable catastrophies but to fight them in a scientific way to their advantage. The designing and execution of the flood control works have, therefore, been receiving serious consideration of the Government and the public in recent years. In this connection a critical study of the meteorological conditions which are favourable for the production of intense rainfall at the sources and catchments of different rivers in West Bengal is very important because it is well known that most of the floods in these rivers are primarily due to such intense rainfall. There are, however, cases in which floods at the mouths of the rivers flowing into the Bay of Bengal are caused by storm waves and heavy rain in association with the inland passage of severe cyclonic storms of Bay origin across the coast. The object of this note is to bring out the principal meteorological conditions in relation to the floods in different parts of West Bengal and to discuss whether it is possible to predict sufficiently in advance the intense rain at the sources and catchments of West Bengal rivers which may ultimately result in the flooding of these rivers.

Meteorological conditions favourable for occurence of heavy rain at the sources and catchments of West Bengal rivers and its effect in relation to the floods of these rivers.

Barring the cases in which floods at the mouths of rivers flowing into the Bay of Bengal are caused by storm waves and heavy rain in association with the inland passage of severe cyclonic storms of Bay origin in pre-monsoon and post-monsoon months just as in the case of Midnapore flood of October 1942, one common feature noticeable about the floods of all West Bengal rivers is that they occur only during June to September when southwest monsoon is normally active over West Bengal and adjoining areas. Another interesting feature about the floods of West Bengal rivers is that simultaneous floods of the rivers in the north and those in the south are but rare. From these observations one can understand that even though active monsoon is responsible for producing intense rain at the sources and catchments of the rivers which may ultimately result in the floods in the respective rivers, the synoptic situation in relation to the floods in the rivers of the northernmost districts of West Bengal is different from that in relation to the floods in the south. It is well known to the Meteorologists that on a day of normal monsoon during June to September an elongated trough extends over the Gangetic plain from NW India and adjoining West Pakistan to Orissa coast and its axis passes from Sriganganagor to Balasore. The monsoon current from the Arabian Sea advancing over southern India and Madhyapradesh meets the monsoon current from the Bay of Bengal along the axis of the trough. Under such normal monsoon conditions fairly widespread rain may occur in West Bengal and neighbourhood but the intensity of such rainfall, even if it is continued for a few days, does not generally result in the flooding of rivers in any part of West Bengal. The rainfall responsible for such floods occurs under an abnormal activity of monsoon under some specific meteorogical conditions. From this meteorological point of view the floods of West Bengal rivers may be classified under two categories viz:- (a) *The floods of the rivers in Gangetic West Bengal some of which originate from Chotanagpur hills*; and (b) *the floods of the rivers in the submontain districts in the north, most of which originate from the eastern Himalayas.*

During the prevalence of southwest monsoon a series of cyclonic depressions or storms form in the north Bay of Bengal and travel in a northwesterly or westerly direction across Orissa-West Bengal coasts. During this season land depressions also form from time to time over the Sunderbans or coastal West Bengal and move in a northwesterly or westerly directions. These depressions and storms intensify the rainfall and concentrate it in their vicinity. If such a storm or depression while moving slowly from West Bengal coast towards Chotanagpur hills under suitable conditions gives intense rain for a few days over and near the source and the catchment of any river in Gangetic West Bengal, it may ultimately lead to a flood under the category "a" above. For instance the intense rain which was responsible for the flood in the Damodar in Sept. '46 occurred under the influence of a depression of the type mentioned above, the track of which is shown in Fig.1. The synoptic situation on 17-9-46 relating to this depres-

sion is shown in Figs. 2 to 5 and some noteworthy falls caused by the depression are given in Table 1.

TABLE 1

Noteworthy daily rainfall during the period 15-9-46 to 18-9-46

Rainfall in inches—September, 1946

Station	*District*	15	16	17	18
Diamond Harbour	24-Parganas	9	—	—	—
Budge Budge	,,	—	6	7	—
Alipore	,,	—	7	—	—
Katwa	Burdwan	—	—	6	—
Asansol	,,	—	—	11	—
Mankar	,,	—	—	7	—
Hetampur	Birbhum	—	—	7	—
Indus	Bankura	—	5	—	—
Sonamukhi	,,	—	7	—	—
Seromonipur	,,	—	8	—	—
Bankura	,,	—	—	7	—
Palasdanga	,,	—	—	11	—
Chatna	,,	—	—	8	—
Saltora	,,	—	—	6	—
Tamluk	Midnapore	9	—	—	—
Kashiary	,,	8	—	—	—
Ghatal	,,	—	8	—	—
Panchet	,,	—	7	—	—
Bhagawanpur	,,	—	7	—	—
Narayangarh	,,	—	9	—	—
Amlagura	,,	—	—	8	—
Howrah	Howrah	5	—	—	—
Uluberia	,,	—	10	—	—
Amta	,,	—	7	—	—
Jamtara	Santal Parganas	—	—	5	—
Sarawan	,,	—	—	8	—
Ramgarh	Hazaribagh	—	—	5	—
Barhi	,,	—	—	10	—
Chatra	,,	—	—	—	9
Hunterganj	,,	—	—	—	12
Bishnupur	Ranchi	—	—	5	—
Bano	,,	—	—	—	11
Palamau	Palamau	—	—		7
Balumath	,,	—	—	—	8
Patan	,,	—	—	—	6
Netorhat	,,	—	—	—	7
Purulia	Manbhum	—	—	5	—
Raghunathpur	,,	—	—	8	—
Manbazar	,,	—	—	8	—
Ghatsila	Singhbhum	—	7	—	—
Bahoragora	,,	—	7	—	—

The depressions and storms in the months June to September as described above seldom take a northerly course after crossing West Bengal coast and as such they can hardly intensify the rainfall and concentrate it over the submontane districts in the north and the adjoining eastern Himalayas. The intense rain which is responsible for the floods of the rivers in the north as shown under category "b" above may occur under a "break" in the monsoon conditions i. e. when the axis of the monsoon trough shifts from its normal position to the foot of the Himalayas. Under this condition the monsoon currents from the Arabian Sea and the Bay of Bengal meet at or near the foot of the eastern Himalayas and cause copious rain over and near the sources and catchments of the rivers originationg from the eastern Himalayas. The rainfall over this area is often intensified under the influence of low pressure waves moving from west to east across the Himalayan region, these low pressure waves tending to strengthen the moist current from the south. Thus if a "break" in the nomsoon condition described above happens to occur simultaneously with the passage of a westerly low pressure wave across the eastern Himalayas, sufficiciently intense and concentrated rainfall occurs in the north which may ultimately result in the floods classified under the category "b". For instance the floods of the rivers in the submontane districts in August '54 occurred under the conditions described above. The synoptic situation on 22-8-54 in relation to this flood is shown in Figs. 6-9 and some noteworthy amounts of rainfall during the period 21-8-44 to 25-8-54 are shown in Table 2.

What have been stated so far are only the two principal meteorological aspects in relation to the floods of the West Bengal rivers in the north and the south respectively. There are other meteorological details which influence favourably or adversely the rainfall expected under the two principal conditions stated above. Those details are, however, beyond the scope of this note.

Prediction of Heavy Rain at the Sources and Catchment of West Bengal River which may ultimately lead to Floods.

From an analysis of the meteorological data received daily from the existing net work of observatories over India and neighbourhood warnings against anticipated heavy rain for different areas including the sources and catchments of West Bengal rivers are issued by India Meteorological Department 24 to 48 hours ahead. Flood forecasts are not envisaged in these warnings. Quantitative estimate of the anticipated precipitation with reference to space and time in the areas concerned in association with significant weather situation is perhaps the first step towards flood forecast. For such an estimation collection of rainfall data at least once daily from a suitably planned net work of stations appropriate to the topography and other local peculiarities of the sources and catchments of the different rivers and their neighbourhood and an elaborate analysis of those data along with a critical analysis of daily weather charts are necessary. The analysis involves the following principal items: —

(1) Location of significant rainfall patterns in

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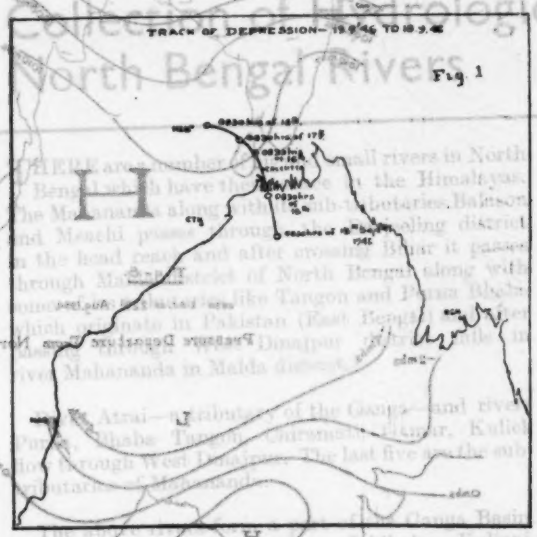


Fig. 1

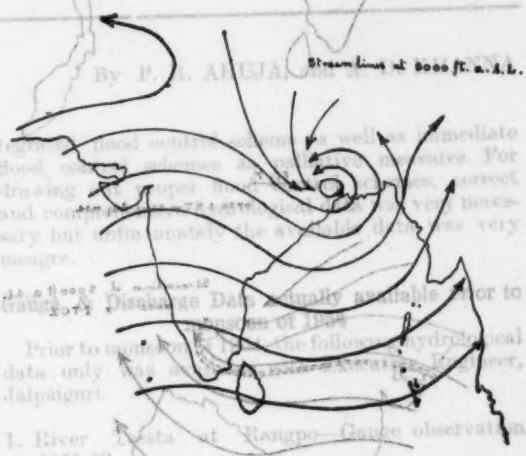


Fig 3.

0730 I.S.T. 17th Sept 1946.

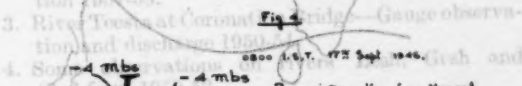


Fig 4.

0800 I.S.T. 17th Sept 1946.

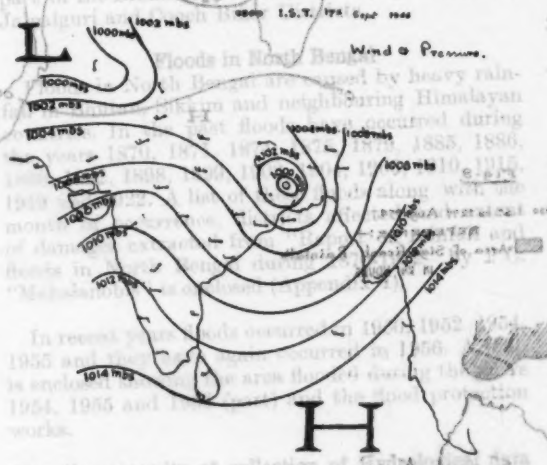
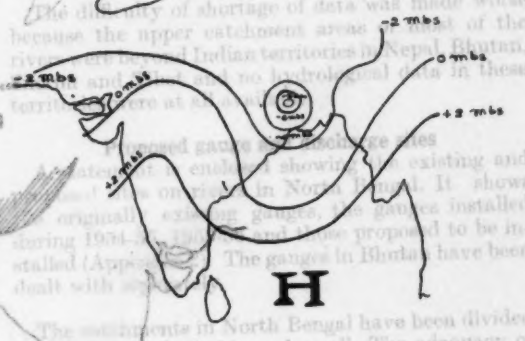


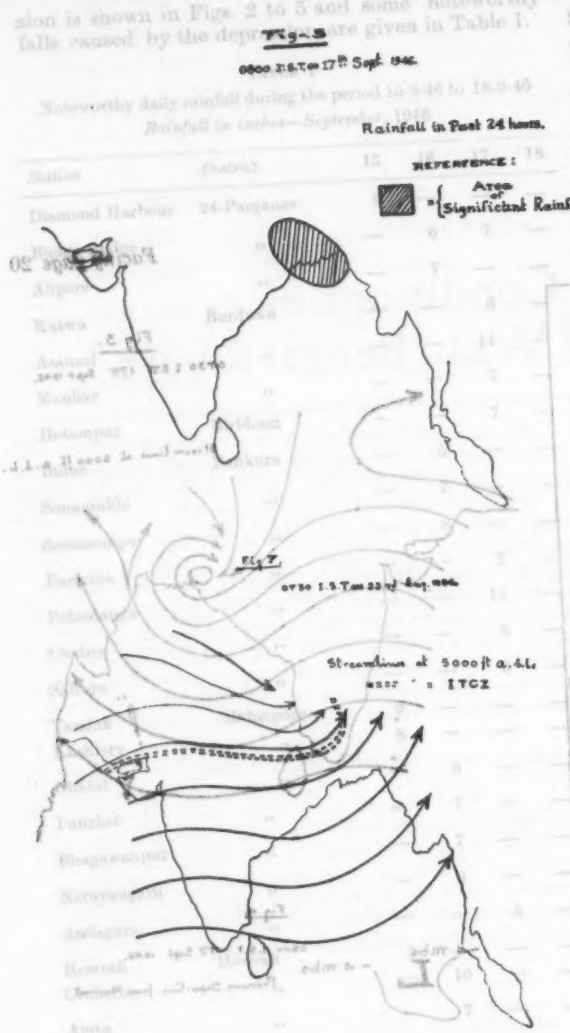
Fig 2.

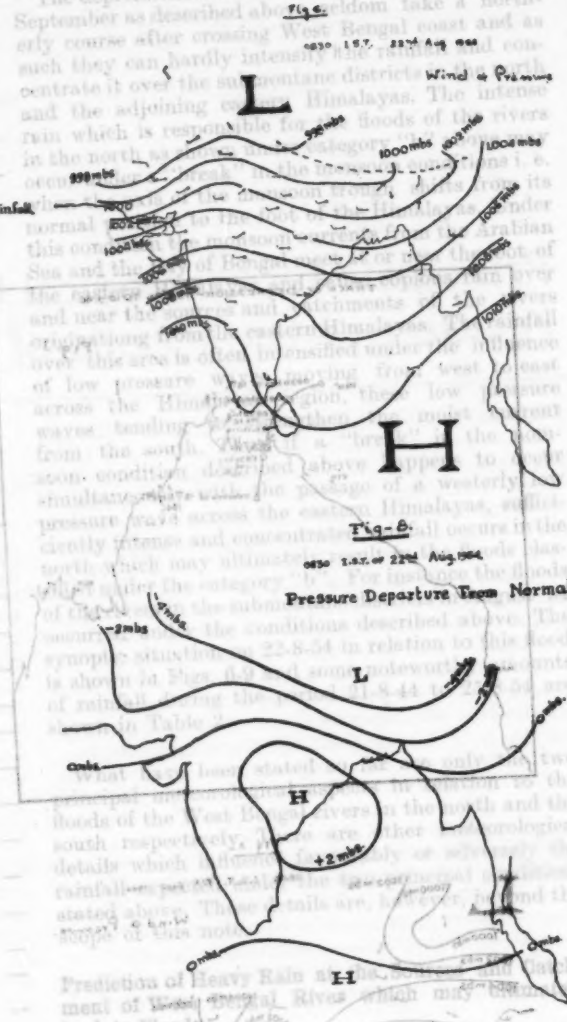
0800 I.S.T. 17th Sept 1946

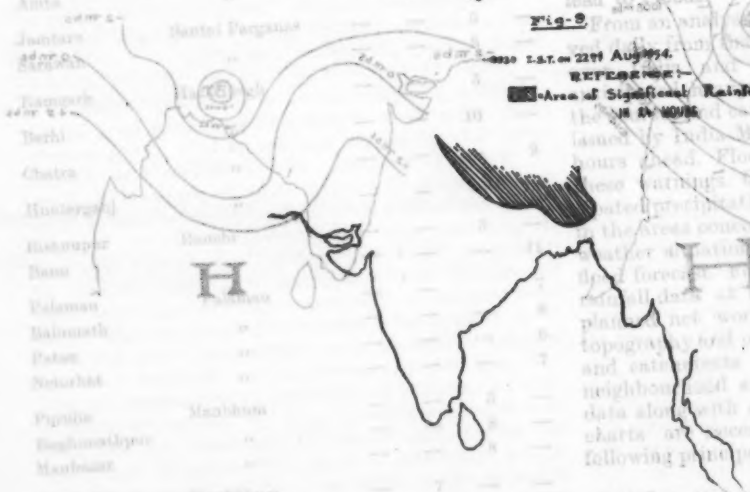
Wind & Pressure.



sion is shown in Figs. 2 to 5 and some noteworthy falls caused by the depr[illegible]are given in Table I.







The depressions and storms in the months June to September as described above seldom take a northerly course after crossing West Bengal coast and as such they can hardly intensify the rainfall and concentrate it over the sub-montane districts of Bihar and the adjoining Himalayas. The intense rain which is responsible for floods of the rivers in the north [illegible] i.e. occurs [illegible] normal [illegible] this condition [illegible] Sea and the [illegible] over the [illegible] and near the [illegible] over this area is [illegible] of low pressure [illegible] across the Himalayas [illegible] from the south. [illegible] simultaneously [illegible] pressure [illegible] the [illegible] circulation and concentration [illegible] north which may ultimately [illegible] of the sub-[illegible] the conditions described above. The [illegible] synoptic situation [illegible] 22-8-54 in relation to this flood is shown in Figs. [illegible] and some noteworthy [illegible] of rainfall during the [illegible] Table [illegible]

[illegible] stated [illegible] only two [illegible] to the floods of the West [illegible] rivers in the north and the south respectively. [illegible] are [illegible] other meteorological details which [illegible] only as [illegible] the rainfall [illegible] over the [illegible] stated above. These details are, however, [illegible] and the scope of this note.

Prediction of Heavy Rain [illegible] Flash-flood [illegible] ment of West Bengal Rivers which may ultimately lead to floods [illegible] from [illegible] meteorological [illegible] network of observatories [illegible] warnings against [illegible] different areas including [illegible] West Bengal rivers are [illegible] Meteorological Department 24 to 48 hours ahead. Flood forecasting [illegible] not envisaged in [illegible] Flood forecasting [illegible] estimate of the anticipated [illegible] intensification with [illegible] and time [illegible] the areas concerned in addition with significant [illegible] perhaps the first step towards [illegible] such an estimation collection of [illegible] once daily from a suitably [illegible] network of stations appropriate to the [illegible] topographical and other local peculiarities of the sources [illegible] and catchments of the different rivers and their [illegible] and an elaborate analysis of those [illegible] with a critical analysis of daily weather [illegible] necessary. The analysis involves the following [illegible]

(1) Location of significant rainfall patterns in

[Continued on page 18

Collection of Hydrological Data of North Bengal Rivers

By P. R. AHUJA, and A. D. KHANNA

THERE are a number of big and small rivers in North Bengal which have their source in the Himalayas. The Mahananda along with its sub-tributaries Balason and Meachi passes through the Darjeeling district in the head reach and after crossing Bihar it passes through Malda district of North Bengal along with some of its tributaries like Tangon and Purna Bhaba which originate in Pakistan (East Bengal) and after passing through West Dinajpur district falls in river Mahananda in Malda district.

River Atrai—a tributary of the Ganga—and rivers Purna, Bhaba Tangon, Chiramati, Gamar, Kulick flow through West Dinajpur. The last five are the sub-tributaries of Mahananda.

The above rivers form a part of the Ganga Basin. The other rivers like Teesta, Jaldhaka, Kaljani, Torsa and Raidak along with their tributaries form part of the Brahamaputra basin. They pass through Jalpaiguri and Cooch Bihar Districts.

Floods in North Bengal

Floods in North Bengal are caused by heavy rainfall in Bhutan, Sikkim and neighbouring Himalayan countries. In the past floods have occurred during the years 1870, 1871, 1874, 1875, 1879, 1885, 1886, 1890, 1892, 1898, 1899, 1902, 1904, 1906, 1910, 1915, 1919 and 1922. A list of these floods along with the month of occurrence, districts affected and extent of damages extracted from "Report on rainfall and floods in North Bengal during 1870-1922" by P.C. "Mahalanobis" is enclosed (Appendix I).

In recent years floods occurred in 1950, 1952, 1954, 1955 and they have again occurred in 1956. A map is enclosed showing the area flooded during the years 1954, 1955 and 1956 (part) and the flood protection works.

How the necessity of collection of Hydrological data was felt

After the severe floods of 1954 in North Bihar the attention of the Government was pointedly drawn to the necessity of adopting effective flood control measures with a view to alleviate the misery and distress caused by the floods. The North Bengal Flood Inquiry Committee which started functioning in May, 1954 was faced with the task of thoroughly studying the flood problems and suggesting an integrated flood control scheme as well as immediate flood control schemes as palliative measures. For drawing out proper flood control schemes, correct and comprehensive hydrological data was very necessary but unfortunately the available data was very meagre.

Gauge & Discharge Data actually available prior to monsoon of 1954

Prior to monsoon of 1954, the following hydrological data only was available with Executive Engineer, Jalpaiguri.

1. River Teesta at Rangpo—Gauge observation 1951-53.
2. River Teesta at Anderson Bridge—Gauge observation 1951-53.
3. River Teesta at Coronation Bridge—Gauge observation and discharge 1950-54.
4. Some observations on rivers Lesh, Gesh and Chel from 1950-52.

The difficulty of shortage of data was made worse because the upper catchment areas of most of the rivers were beyond Indian territories in Nepal, Bhutan, Sikkim and Tibet and no hydrological data in these territories were at all available.

Proposed gauge and discharge sites

A statement is enclosed showing the existing and proposed sites on rivers in North Bengal. It shows the originally existing gauges, the gauges installed during 1954-55, 1955-56 and those proposed to be installed (Appendix 2). The gauges in Bhutan have been dealt with separately.

The catchments in North Bengal have been divided into 13 basins both big and small. The adequacy of gauge and discharge sites in each basin has been examined. The discharge sites have been proposed to be set up in major tributaries before their confluence with the main rivers and on the main rivers below the junctions. In this way the additional discharge of the main river below the junction is known.

Some gauge and discharge sites have been proposed

in the upper reaches of the catchments in order that the data so obtained may be useful for planning flood control works.

A number of gauge sites have been proposed so that they may be helpful for knowing river slopes, high flood levels and for flood warning purposes etc.

*Basin No.*1 (Teesta Basin)
Part of this basin lies in Sikkim and part in North Bengal. In the Sikkim portion one Gauge and Discharge site was established in 1954-55 while five more gauge and discharge sites have been proposed. In the North Bengal portion of this basin there were originally three gauge and discharge sites and one gauge site. In 1954-55 two more gauge and discharge sites were fixed while in 1955-56 five gauge and discharge and two gauge sites were fixed. The gauge site at Barnes ghat railway bridge has been proposed to be converted into a gauge and discharge site while two more gauge and discharge sites have been recommended.

Basin No. 2 (Jaldhaka-Daina Basin)
There were no gauge or discharge sites in this basin before 1954. One gauge and discharge site was established in 1954-55. Proposals have been made for fixing three gauge and discharge sites. One of these is on Jaldhaka at Nagrakata Road Bridge and one each on Diana and Rotikhola at crossing with railway line.

Basin No. 3 (Jaldhaka Basin)
There are no existing gauge or discharge sites in this basin. Proposals have been made for establishing two gauge and discharge sites and two gauge sites. A gauge site will be fixed on Burhi Torsa at Falkata, Dhupguri road. The proposed gauge and discharge sites on Jaldhaka after confluence with Dudiya and the one at Sitalkuchi-Dinhata road are obviously necessary.

Basin No. 4 (Torsa Basin)
The basin lies in North Bengal and Bhutan. In the North Bengal portion of this basin, two gauge sites and one gauge and discharge site were established during 1954-55 while one more gauge and discharge site at Hashi Mara railway bridge has been proposed.

Basin No. 5 (Kaljani Basin)
One gauge site and one gauge and discharge site were installed during 1955-56. One gauge and discharge site at Hamiltonganj has been proposed in this basin.

Basin No. 6 (Jaugti Basin)
There are no gauge and discharge sites in this basin. One gauge site each at Alipurduar, Kumargram Road and Cooch Behar Toofanganj road have been proposed.

Basin Nos. 7 & 8 (Raidok and Sankosh Basins)
The basins lie in North Bengal and Bhutan. In the North Bengal portion, one gauge site and one gauge and discharge site were established in 1954-55. Two gauge and discharge sites have been proposed.

Basin No. 9 (Jamuna Basin)
A very small portion of this basin comes in Indian territory. There are no gauge and discharge stations in this catchment and none have been proposed.

Basin No. 10 (Atrai Basin)
There are no gauge or discharge sites existing in this catchment. Two gauge sites have been proposed.

Basin No. 11 (Punar Bhaba Basin)
There are no gauge or discharge sites in this basin. One gauge site has been proposed.

Basin No. 12 (Tangon Basin)
There are no gauge or discharge sites existing in this catchment. Two gauge sites have been proposed.

Basin No. 13 (Mahananda Basin)
This basin lies partly in North Bengal and partly in Bhutan. In the North Bengal portion prior to 1954, there was only one gauge site in this catchment at English Bazar. In 1955-56, gauge and discharge site was established at Siliguri. Eleven gauge sites have been proposed now in this portion. All of them fall in Malda and West Dinajpur districts.

Gauge and discharge stations in Bhutan have been given separately.

The above stations have been proposed considering the present needs. The needs can be reviewed from time to time and fresh proposals made when necessary.

Map showing the existing and proposed gauge and discharge sites is enclosed (Map 2).

Silt Observation Stations

The State authorities opened some silt observation stations after 1954 which are shown in the accompanying map (Map 3). The silt data received from these stations will be analysed in the Silt and Construction Materials Directorate of the C.W.& P.C.

Collection of River Gauge and Rainfall Data and Installation of Wireless sets in Bhutan

As the floods in West Bengal are mainly due to heavy precipitation in Bhutan and neighbouring countries, it was considered essential to obtain some basic data of rainfall, river gauges, discharge and silt etc. which may be helpful in designing proper flood control measures. It was also necessary to have wireless stations for giving information regarding rainfall and gauge readings of the river during flood season.

The wireless sets were to be of 100 watts, simple type which could transmit from 100 to 200 miles without the use of any code.

With the consent of the Maharaja of Bhutan the work of establishing rain gauges, river gauges, wireless stations and discharge and silt observation sites was divided in different stages. In 1955 the various types of stations were established as in table below.

Map 4 shows raingauges, rivergauges, wireless and discharge sites in Bhutan.

Issue of Flood Forecasts by Regional Meteorological Centres

At the 89th meeting of the Joint Meteorological Committee the need for forecasting heavy rainfall for the catchments was stressed by the C.W. & P.C. The Indian Meteorological Department pointed out that heavy rainfall warning and heavy rainfall reports

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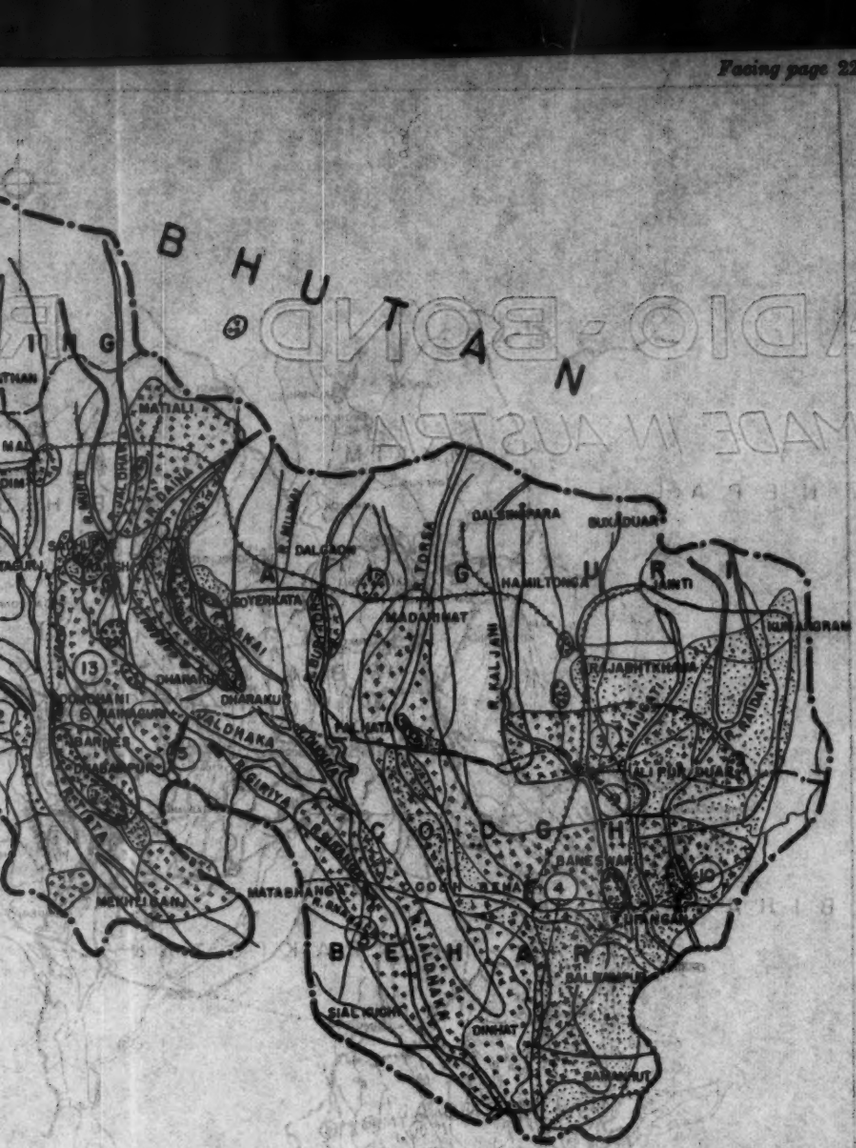


FLOOD PROTECTION WORKS UNDER EXECUTION.

1.	SILIGURI TOWN PROTECTION WORKS ON RIVER MAHANANDA.	
2.	JALPAIGURI " " " " "	TISTA
3.	ALIPURDUAR " " " " "	KALJANI (ABOVE RLY. BRIDGE)
4.	COOCH BEHAR " " " " "	TORSA
5.	MATABHANGA " " " " "	JALDHAKA & SUTANGA
6.	BARNES DOMOHANI EMBANKMENT " "	TISTA.
7.	PHANSIDEWA VILLAGE PROTECTION WORKS " "	MAHANANDA

PROPOSED WORKS.

8.	MATIGARA VILLAGE PROTECTION WORKS ON RIVER BALASAN.	
9.	ALIPURDUAR TOWN " " " "	KALJANI (BELOW RLY. BRIDGE)
10.	TUFANGANJ " " " " "	RAIDAK.
11.	SAKTIGARH COLONY " " " "	MAHANANDA.
12.	PROTECTING RIGHT BANK OF RIVER CHEL ABOVE RLY. BRIDGE.	
13.	CONSTRUCTING EMBANKMENT ON RIGHT BANK OF RIVER JALDHAKA. FROM N. H. 31 TO AMGURI.	
14.	PROTECTION ON THE LEFT BANK OF RIVER LITTLE RANJIT NEAR PULIMARI	

REFERENCES

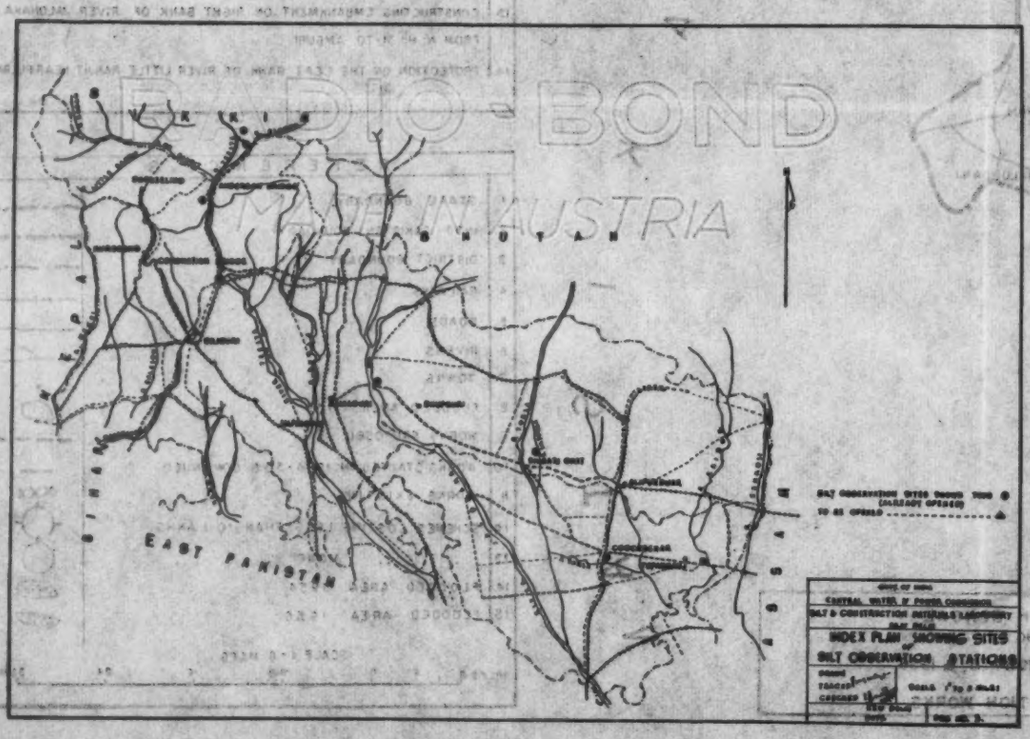
1.	STATE BOUNDARY.
2.	INDO-PAKISTAN BOUNDARY.
3.	DISTRICT BOUNDARY
4.	RAILWAYS.
5.	ROADS.
6.	RIVERS.
7.	TOWNS.
8.	FLOODED AREA 1955
9.	WORKS PROPOSED.
10.	WORKS STARTED IN 1954-55 & CONTINUED.
11.	WORKS EXISTING.
12.	SCHEMES COSTING LESS THAN 10 LAKHS
13.	" " MORE " " "
14.	FLOODED AREA 1954.
15.	FLOODED AREA. 1956.

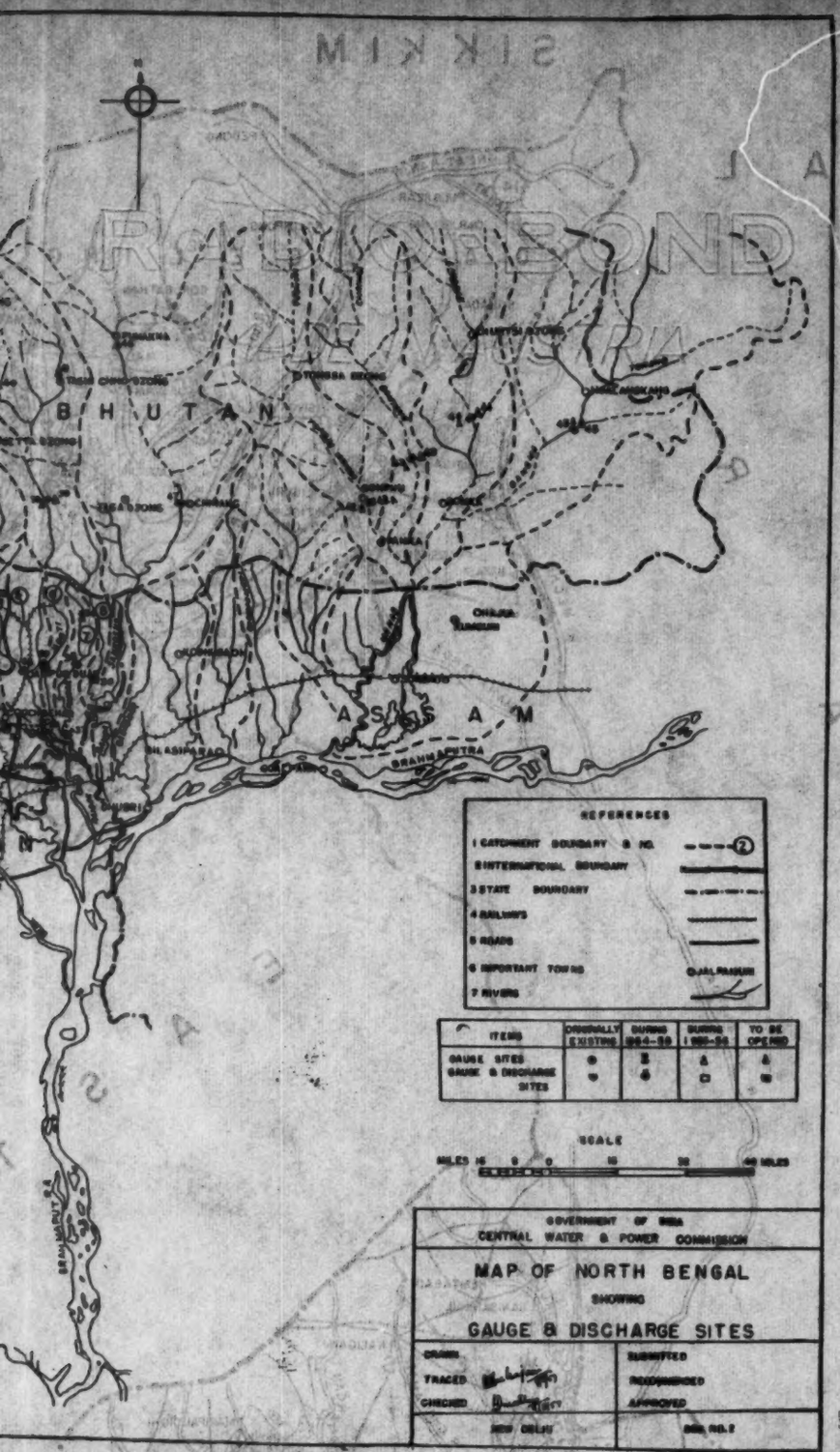
SCALE 1" = 8 MILES.

MILES 0 4 8 16 24 32 MILES

OF NORTH BENGAL
SHOWING
D AREAS 1954,55, & 1956
&
O PROTECTION WORKS

SIKKIM
NEPAL
W. BENGAL
BIHAR
E. PAKISTAN
SW. BENGAL


BHUTAN
EAST PAKISTAN
INDEX PLAN SHOWING SITES
SILT OBSERVATION STATIONS


SIKKIM
BHUTAN
ASSAM
BRAHMAPUTRA
REFERENCES
1 CATCHMENT BOUNDARY & NO.
2 INTERNATIONAL BOUNDARY
3 STATE BOUNDARY
4 RAILWAYS
5 ROADS
6 IMPORTANT TOWNS
7 RIVERS
ITEMS
ORIGINALLY EXISTING
DURING 1964-65
DURING 1965-66
TO BE OPENED
GAUGE SITES
GAUGE & DISCHARGE SITES
SCALE
GOVERNMENT OF INDIA
CENTRAL WATER & POWER COMMISSION
MAP OF NORTH BENGAL
SHOWING
GAUGE & DISCHARGE SITES
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED

APPENDIX I

List of floods in North Bengal during 1870-1922

S. No.	Year	Flood month	Rainfall Period	Affected District	Intensity of Flood	Extent of Damage	Remarks
1.	1870	July & Aug.	July and Aug.	Rajshahi & Pabna	(c) Moderate	Great damage to crops	Overflow of the Ganges. High level of the Brahmaputra
2.	1871	End of Aug. to 2nd week of September	September	Malda & Rajshahi (Lower part)	(b) Severe & extensive	Considerable loss of cattle	Excess rainfall. Exceptionally high level of the Ganges
3.	1874	September	29th Aug. to 15th September	Rajshahi & Pabna	(c) Moderate	Great damage to crops	High level of the Ganges and of the Brahmaputra. Local excess of rainfall.
4.	1875	August	....	Pabna	(d) Slight	Damage to crops	High level of the Ganges. Heavy local falls
5.	1879	August	....	Rajshahi	(d) -do-	-do-	High level of the Ganges caused by heavy falls in the U. P. & Bihar
6.	1885	September	August & Sept.	Rajshahi, Malda & Dinajpur	(b) Severe	Considerable loss of human life & cattle and destruction of property	Heavy local falls. Very high level of the Ganges
7.	1886	September	6th to 11th Sept.	Bogra, Malda Rajshahi & Pabna	(c) Moderate	Destruction of houses & property	Excess rainfall. High level: Ganges and Brahmaputra
8	1890	August	....	Pabna	(c) -do-	Roads seriously damaged	Overflow of the Ganges
9.	1890	August	....	Darjeeling	(d) slight	-do-	High level of the Tista
10.	1892	July	1st to 8th July	Jalpaiguri, Darjeeling, Rangpur and Dinajpur	(b) Very severe	Considerable loss of human life & destruction of cattle; great damage to roads and property	V.heavy falls. High level of the Tista, Mahananda Dharla and Atrai. Serious holding of water in Dinajpur & Rangpur by the Railway line
11.	1892	July	-do-	Pabna	(d) Slight	....	Overflow of the Ganges
12.	1898	September	September	Darjeeling	(c) Moderate	Damage to crops	Local rainfall
13.	1899	September	September	Darjeeling	(a) Very severe	Destructive landslips, considerable loss of life and unprecedented damage to roads, bridges and buildings	Very heavy rainfall on the 24th & 25th September
14.	1902	August	....	Cochbehar & Rangpur	(d) slight	....	Excess of rainfall
15.	1902	September	September	Jalpaiguri	(b) Severe	Ten lives lost; damage to rly.; Serious loss of cattle	Heavy falls in the hills. Overflow in the Tista
16.	1904	August	....	Malda	(d) Slight	....	Exceptionally high level of the Ganges
17.	1906	August & September	27th July to 5th Aug. 27th July to 20th August	Jalpaiguri, Cooch-behar & Darjeeling	(b) Severe	Extensive damage to crops and property	Heavy rainfall
18.	1906	August. & September	27th July to 5th Aug. 20th July to 20th August	Pabna, Rajshahi & Malda	(d) Slight	Famine conditions in Malda & Rajshahi	Abnormal rise of the Brahmaputra
19.	1910	July	8th to 31st July	Cooch behar & Jalpaiguri	(c) Moderate	Several breaches in the Railway line	Excessive local rainfall
20.	1910	July	Do.	Pabna	(d) Slight	....	Abnormally high level of the Brahmaputra
21.	1915	August	7th to 15th Aug.	Duars	(d) -do-	Damage to crops	Heavy local rainfall
22.	1915	1st Week of September	....	Pabna	(d) -do-	Villages under water	A high river level
23.	1918	End of Aug.	18th to 27th August	Rajshahi, Bogra, Dinajpur, Rangpur, Pabna & Malda	(b) Severe	Several deaths & considerable damage to crops & property	Heavy cyclonic rainfall on the 24th, 25th and 26th August
24.	1919	End of Aug. & 1st week of September	....	Pabna	(d) Slight	....	Overflow from the Ganges
25.	1922	Last week of Sept. to middle of October	Week ending 27th September	400 Sq. miles in Bogra, 1200 Sq. miles in Rajshahi & a small portion in Pabna and Dinajpur	(a) Very severe & extensive	Estimated loss of property worth 6 crores	Exceptionally heavy cyclonic precipitation in the week ending 27th Sept.

APPENDIX 2.

Statement showing existing and proposed Gauge and discharge sites on Rivers in North Bengal.

D Stands for Gauge and Discharge
D Stands for Gauge.
No. sites in Basin No. 9.

Site No.	*Name of River or Tributary*	*Originally existing*	*Installed during 1954-1955.*	*Installed during 1955-1956.*	*Proposed to be installed.*
		Teesta Basin (No. 1)			
		1-(Sikkim portion)			
6.	**Teesta**	—	**Rangpo—(G&D)**	—	
2.	**Lachen**	—	—	—	**Lachen (G&D)**
3.	**Lachung**	—	—	—	**Lachung (G&D)**
4.	**Teesta**	—	—	—	**Chungthang (G&D)**
5.	**Teesta**	—	—	—	**Dikchu (G&D)**
14.	**Rangit**	—	—	—	**Nayabazar (G&D)**
		1-(North Bengal portion)			
8.	**Teesta**	**Anderson (G&D) Bridge.**	—	—	—
9.	**Teesta**	**Coronation (G&D) Bridge.**	—	—	—
10.	**Teesta**	**Jalpaiguri (G&D)**	—	—	—
12.	**Karala**	**Mashkalaibari (G)**	—	—	—
13.	**Rangpo**	—	**Rangpo (G&D)**	—	—
16.	**Rangit**	—	**Manjhitar (G&D)**	—	—
17.	**Relli**	—	—	**Nazok (G&D)**	—
18.	**Relli**	—	—	**Char Khola (G)**	—
19.	**Lish**	—	—	**Railway Br. (G&D)**	—
20.	**Gish**	—	—	**Road Br. (G&D)**	—
21.	**Chel**	—	—	**Road Br. (G&D)**	—
22.	**Neora**	—	—	**Road Br. (G&D)**	—
11.	**Teesta**	—	—	**Barneseghat (G)**	—
11A.	**Teesta**	—	—	—	**Barneshghat (G&D) Site No. 11 to be converted into (G&D**
7.	**Teesta**	—	—	—	**Melli (G&D)**
15.	**Ramman**	—	—	—	**Nayabazar (G&D)**
		Jaldhaka-Daina Basin (No. 2)			
		(North Bengal)			
24.	**Jaldhaka**	—	**N.H. 31 Br. (G&D)**	—	—
23.	**Jaldhaka**	—	—	—	**Nagrakata Rd. Br**
26.	**Daina**	—	—	—	**Rly. Br. (G&D)**
17.	**Reti Khola**	—	—	—	**Rly. Br. (G&D)**
		Jaldhaka Basin (No. 3)			
		(North Bengal)			
25.	**Jaldhaka**	—	—	—	**Matha Bhanga (G)**
65.	**Jaldhaka**	—	—	—	**Sital Kuchi (G&D) Dinhata Rd.**
66.	**Jaldhaka**	—	—	—	**Confluence with Dudiya (G&D)**
67.	**Burhi Torsa**	—	—	—	**Falkata-Dhupgrui Rd. (G)**

Site No.	Name of River	Originally existing	Installed during 1954-55.	Installed during 1955-56.	Proposed to be installed.
		4—(North Bengal portion)			
29.	Torsa	—	Rd. X-ing between Falkata & Alipurduar (G).	—	—
30.	Torsa	—	Rd. Br. at Cooch-Behar (G&D)	—	—
31.	Siltorsa	—	Silbaighat (G)	—	—
28.	Torsa	—	—	—	Rly. Bridge Hashi Mara (G.&D)
		Kaljani Basin (No.5) (North Bengal)			
33.	Kaljani	—	—	Confluence with Torsa (G).	—
32.	Kaljani (Gabur Basra)	—	—	—	Hamiltonganj (G&D)
68.	Kaljani	—	—	Alipurduar (G&D)	—
		Jaugti Basin (No. 6) (North Bengal)			
69.	Jaugti	—	—	—	Alipurduar Kumargram Rd (G)
70.	Jaugti	—	—	—	Coooh Behar Rd. Toofanganj (G)
		Sankosh and Raidok Basin No. 7&8. (North Bengal portion)			
34.	Raidok	—	Jainti Dhowla Rd(G)	—	—
37.	Raidok	—	N.H. Br. (G&D)	—	—
35.	Raidok	—	—	—	Rly, Br. (G&D).
36.	Raidok	—	—	—	Rly. Br. (G&D).
		Atrai Basin (No. 10) (North Bengal)			
61.	Atrai	—	—	—	Kumargram (G).
64.	Atrai	—	—	—	Balurghat (G).
		Punar Bhaba Basin (No. 11) (North Bengal)			
60.	Punarbhaba	—	—	—	Gangrampur (G).
		Tangon Basin (No. 12). (North Bengal).			
49.	Tangon	—	—	—	Ahio (G).
58.	Tangon	—	—	—	Radhikapur Rly. Station (G).
		Mahananda Basin (No. 13). (North Bengal).			
1.	Mahananda	—	—	Siliguri (G&D)	—
48.	Mahananda	English Bazar (G)	—	—	—
50.	Pagla	—	—	—	Manik Chak (G)
51.	Mora Mahananda	—	—	—	Kusidi (G)
52.	Kalindri	—	—	—	Nagharia (G)
53.	Kankar	—	—	—	Bhalukha (G)
54.	Mora Mahananda	—	—	—	Pukhuria (G)
55.	Charamati	—	—	—	Kanchan (G)
56.	Mahananda	—	—	—	Barsoi Rly. Station (G)
57.	Nagar	—	—	—	Kachan Railway Station (G)
59.	Kulick	—	—	—	Khormugaghat (G)
62.	Ganari	—	—	—	Itahar (G)
63.	Sui.	—	—	—	Baisnabtala (G)

APPENDIX 3

Water-Year Book periods

The water year from 1st April to 31st March is divided into the following periods :—

I	Pre-monsoon	1st April to 31st May.
II	Monsoon	1st June to 30th September.
III	Post-Monsoon	1st October to 31st December
IV	Winter	1st January to 31st March.

For the working out ten-day averages, the period will be sub-divided as below :—

Period No.	*Sub-period No.*	*Dates*	
I	1	April	1-10
	2	,,	11-20
	3	,,	21-30
	4	May	1-10
	5	,,	11-20
	6	,,	21-31
I	7	June	1-10
	8	,,	11-20
	9		21-30
	10	July	1-10
	11	,,	11-20
	12	,,	21-31
	13	Aug.	1-10
	14	,,	11-20
	15	,,	21-31
	16	Sept	1-10
	17	,,	11-20
	18	,,	21-30
III	19	Oct.	1-10
	20	,,	11-20
	21	,,	21-31
	22	Nov.	1-10
	23	,,	11-20
	24	,,	21-30
	25	Dec.	1-10
	26	,,	11-20
	27	,,	21-31
IV	28	Jan.	1-10
	29	,,	11-20
	30	,,	21-31
	31	Feb.	1-10
	32	,,	11-20
	33	,,	21-28
	34	March	1-10
	35	,,	11-20
	36	,,	21-31

APPENDIX 4

.....BASIN

Serial No.....

Distribution of the Catchment Area

1	..	..	..	Sq. miles.
2	..	..	..	Sq. miles.
			Total	Sq. miles.

Details of Area by Sub-Basins

Serial No of Sub-basin	*Name of Sub-basin*	*Area in sq. miles in each State*				*Total*
		x	y	z	etc.	

APPENDIX 5

List of Meteorological Observatories

.....BASIN

Serial No.....

List of Meteorological Observatories

Name of basin or sub-basin.	*Place of observatory.*	*Class of Observatory*	*REMARKS*
1	2	3	4

Note :—(1) New Stations opened during the year marked with.*

(2) Type of instruments in the various classes of observatories should be given in remarks column.

Name of Basin

No. of Sub Basin	Name of Sub Basin	Rain-gauge Station	January		February		March		April		May		June	
			Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall

C.W.I.N.C. H-20

Name of Basin/Sub-basin

TEMPERATUR

No. of sub-basin	Name of sub-basin	Name of station with class	X	Y	Z d	Z w	X	Y	Z d	Z w	X	Y	Z d	Z w

X : Monthly average of max. temp. Y : Monthly average of min. temp.

GAUGE AN

Year : Serial No.

Period	Sub-period	Date	Main River : Gauge/ Discharge Site : R. L. of Zero of Gauge :		Main River : Gauge/ Discharge Site R. L. of Zero of Guage :		Main River : Gauge/ Discharge Site R. L. of Zero of Gauge :	
			Gauge in feet	Discharge in cusecs	Gauge in feet	Discharge in cusecs	Gauge in feet	Discharge in cusecs

GAUGE

Name of Basin :

Period	Sub-period	Date	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge :
			Gauge in feet	Gauge in feet	Gauge in feet	Gauge in feet	Gauge in feet
1	2	3	4	5	6	7	8

RADIO BOND MADE IN AUSTRIA

Serial No. of Basin Year

June		July		August		September		October		November		December					
Max. daily Rainfall		Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Rainfall	Max. daily Rainfall	Total Monsoon Rainfall	Total Annual Rainfall	Raingauge Station	Remarks

RATURE DATA

Appendix 7

Serial No. of Basin/Sub-Basin Year

														Name of station with class	Remarks.
Z d	Z w	X	Y	Z d	Z w	X	Y	Z d	Z w	X	Y	Z d	Z w		

Z_d : Mouthly average of dry bulb thermometer reading Z_w : Monthly average of wet bulb thermometer reading

GE AND DISCHARGE DATA

Appendix 8

Name Basin/Sub-Basin

	Inflow		Main River :		Main River :		Main River :			
	Gauge/ Discharge Site : R. L. of Zero of Gauge :		Gauge/ Discharge Site : R. L. Zero of Gauge :		Gauge/ Discharge Site : R. L. of Zero of Gauge :		Gauge/ Discharge Site : R. L. of Zero of Gauge :		Date	Remarks.
ischarge in usecs	Gauge in feet	Discharge in cusecs	Gauge in feet	Discharge in cusecs	Gauge in feet	Discharge in cusecs	Gauge in feet	Discharge in cusecs		

GAUGE DATA

Appendix 9

Serial No. Year :

iver : Site : Zero ge :	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge :	Main River : Gauge Site : R.L. of Zero of Gauge :	Date	Remarks
	Gauge in feet	Gauge in feet	Gauge in feet	Gauge in feet	Gauge in feet	Gauge in feet		
	9	10	11	12	13	14	15	16

BRADO-BOND MADE IN AUSTRIA

1. *River*	*Raingauges*	*River gauges*	*Wireless Sets.*
1. Torsa	Sombe Dzong	Sombe Dzong	Sombe Dzong
2. Raidok	Chbuka Dzong	Chbuka Dzong	Chbuka Dzong
3. Manas			
(*i*) Tongsa (Mangde)	Tongsa Dzong	—	—
	Gonphu	Gonphu	Gonphu
(*ii*) Bumtang	Lhuntsi Dzong	—	—
	Nimgong	Nimgong	Nimgong
(*iii*) Lhobrak	Monka	Monka	Monka
(*iv*) Kulong	Yangtsi Dzong.	—	—
	Tashi Gang Dzong.	Tashi Gang Dzong.	Tashi Gang Dzong.
	Chungkar	—	—
Total	Ten	Six	Six

In 1955-56 the following stations were established :—

1. Torsa	Daphu	—	—
2. Raidak	Tashi Chho Dzong.	Tashi Chho Dzong.	
3. Sankosh	—	Phodrang	Phodrang
	Taga Dzong	—	—
	Doronagaon	—	—
	—	Chirang	Chirang.
Total :	Four	Three	Two
Total installed up to 1956.	Fourteen	Nine	Eight

The following stations have still to be established and necessary action in this connection is being taken :—

River	*Raingauges*	*Rivergauges*	*Discharge & silt observation sites.*
1. Torsa	—	—	Sombe Dzong
2. Raidak	Paro Dzong	Paro Dzong	Chbuka Dzong
	Byaradingka	—	—
3. Sankosh	Punakha	—	Chirang
	Phodrang		
4. Manas		—	—
(*i*) Tongsa (Mangde) (If possible)	Panka (If)	—	Gonphu
(*ii*) Bumtang	—	—	Nimgong
(*iii*) Lhobrak	—	—	Monka
(*iv*) Kulong (If possible)	Piekao —	—	Tashi Gang Dzong
Total to be installed	Six	One	Seven

were sent to those who required them by previous arrangements. Accordingly, the CW&PC have written to the State Chief Engineers to examine the requirements of each river basin in this respect and to intimate the respective regions for which such heavy rainfall forecasts are required, to enable suitable arrangements to be made with the Director General of Observatories, Indian Meteorological Department.

Flood Warning Equipment under the TCM Aid Programme

The following flood warning equipments under the T.C.M. Aid Programme have been ordered for experimental purposes.

(*a*) *Radio Operated River Gauges*

Two sets of 'Radio Operated River Gauges' along with the receiving sets are being obtained. It is proposed to locate one set at Barahkshetra on the Kosi river and the other on the Sutlej at Bhakra where their performance will be tested. Action is being taken by the C.W. & P. Research Station, Poona to start research on the improvement of coding device of the above river gauges.

(*b*) *Radio Operated Rain Gauges*

Two sets of 'Radio Operated Rain Gauges' along with their receiving sets are also being obtained. These sets will be assigned to the Indian Meteorological Department, who will instal one set at Delhi and the other at Poona to test their performance. The I.M.D. is taking action to start research on the development of coding device for these raingauges.

(*c*) *Radio Survey Equipment*

Two sets of 'Mobile Transmitter Receiver Sets' and two 'Packset Transmitter Receiver Sets' are being procured. These sets are meant for conducting preliminary radio propagation survey in connection with the proposed flood warning network in India. They would help in determining suitable locations for raingauge and rivergauge sites.

Water-Year Books

Hydrological data volumes and water Year Books for some of the basins on which projects have been taken up for investigation or execution by the C.W. & P.C. have been brought out by the C.W. & P.C. It is suggested that the hydrological data for North Bengal rivers may be published in the forms vide Appendices 3-9 for facility of planning flood control schemes.

Basinwise reports of Rivers in West Bengal

The Flood Investigation Division, West Bengal under the C.W. & P.C. is engaged at present on the preparation of basinwise reports of rivers in West Bengal. The basinwise report on Teesta river is nearly completed and the report of Jaldhaka river has made considerable progress. These reports will be followed by the basinwise reports on other rivers. Besides general information about the basin like topography, geology, economics, industries, population, cattle census, communications in the basin the reports will include the rainfall gauge, discharge and silt data. These reports will be useful in preparing integrated flood control and development plans of the basins.

Acknowledgements :

The assistance rendered by Sva, Dalip Singh, E.A.D., M.B. Kumar & R. L. Kapoor, Design Assistants, B. D. Juneja, Junior Draftsman, Kartar Singh, Tracer and B. C. Kapoor, Steno-typist in the preparation of this paper is hereby acknowledged.

Hydro-Meteorological Studies of Damodar and Mayurakshi Catchments

By K. N. RAO

THE importance of detailed hydrometeorological studies of river catchments as a valuable aid in planing multipurpose projects is well known. We have studied the hydrology of a number of river catchments in the past few years. The main results of hydro-meteorological studies of the Damodar (1953) and Mayurakshi catchments (1954) will be summarised in the present paper.

DAMODAR CATCHMENT

The origin of the Damodar river is in the hills of Chota Nagpur at a height of about 2000 ft. a.m.s.l. It flows in a southeasterly direction entering the deltaic plains below Raniganj. Near Burdwan the river abruptly changes its course to a southerly direction and joins Hooghly 30 miles below Calcutta. Its slope during the first 150 miles is about 10ft. per mile, during the next 100 miles 3 ft. per mile and during the last 90 miles about 1 ft. per mile. The Barakar river which joins the Damodar when it emerges from the hills is the main tributary.

The upper portion of the catchment consists of rough hilly regions and the lower of flat deltaic plains. Considerable land erosion has taken place in the upper portion and it is cut up by many deep gullies. The portion of the catchment studied is the area above Raniganj and is shown in Fig. 1.

Heavy rainfall over the area is mainly associated with the passage of depressions and storms from the Bay of Bengal and depressions formed over land. The average number of depressions forming in the Bay of Bengal in each of the months July to October is 2. The average for June is one. The depressions in the months June to September move mostly in a west-northwesterly direction and cause rainfall over west Bengal and adjoining areas. The predominant directions of wind during these months are E/S and SW/NW depending on the position of the axis of the monsoon trough. The percentage of occasions of surface wind at Asansol is as below.

	June		*July*		*August*		*Sept.*		*October*	
	M	*A*	*M*	*A*	*M*	*A*	*M*	*A*	*M*	*A*
E/S	63	63	56	55	49	52	38	52	19	32
SW/NW	25	23	28	23	32	22	39	23	47	28

M—Morning A—Afternoon

The main feature of the rainfall of the catchment are given in the following table. The mean annual rainfall of the catchment is 51″.

TABLE 1

Seasonal rainfall of the Damodar Catchment

	June-Sept.	*June-Oct.*	*Annual*
Mean (1891-1950)	41.73″	44.89″	51.33″
Seasonal rainfall as percentage of Annual.	82%	88%	
Standard Deviation	6.13	7.23	
Mean Deviation	5.06	6.00	
Coefficient of Variation (%)	15	16	
Highest	53.56	64.04	
Percentage of Mean	128	134	
Lowest	28.36	33.04	
Percentage of Mean	69	74	

Frequency distribution (1891-1950) :

Range (inches)	*Frequency*	
28.0-31.99	3	
32	7	4
36	16	11
40	12	13
44	10	10
48	8	9
52	4	8
56	—	3
60	—	1
64	—	1

Nature of Distribution:			
g_1	0.027	0.468	Distribution is normal.
S.E.(g_1)	0.309	0.309	
g_2	0.616	0.300	
S.E.(g_2)	0.608	0.608	
Number of Rainy days (1 cent or more)	110	123	
Standard Deviation	6.1	1.3	
Range	94-122	98-149	
Decade Averages			
1891-1900		42.43	45.23
1901-1910		39.21	41.23
1911-1920		41.29	45.15
1921-1930		43.66	44.20
1931-1940		40.27	43.32
1941-1950		43.55	47.19
Regression coefficient of Rainfall on years		.0325	.0537 (These are not significant)

The distribution of seasonal rainfall is normal. There has been no significant change in rainfall during the past 60 years. Seasonal rainfall will lie within $\pm 10\%$ of the average in 50% of the years. It will lie within $\pm 20\%$ of the average in about 80% of the years. The highest and lowest seasonal rainfall is not likely to fall outside the limits 140% and 60% of the normal respectively. We will now consider daily and storm rainfall. Frequency distributions of daily and five-day rainfall based on data for the period 1891 to 1950 are given below.

TABLE 2

One day rainfall				*Five-day rainfall*			
Cents	*Frequency*	*Cents*	*Frequency*	*Cents*	*Frequency*	*Cents*	*Frequency*
1-20	332	101-200	424	1-100	3291	601-700	35
21-40	1698	201-300	60	-200	2482	-800	22
41-60	1026	301-400	8	-300	1393	-900	4
61-80	536	401-500	3	-400	651	1000	5
81-100	303			-500	309	-1100	5
				-600	111	-1200	1

Similar tables for 2-4 and 6-7 consecutive days have also been prepared. On an average about eight days with mean rainfall of the catchment greater than 1″ may be expected in a year. The average frequency of five-day rainfall exceeding 6″ is once a year. Frequency distributions of rainfall in one to seven days are shown in Figs. 2 and 3.

Heaviest rainfall

The highest rainfall at any of the stations was 12.8″ at Kodarma in August 1917. The highest rainfall in 24 hrs. recorded by 18 of the 29 raingauges is less than 10″. Only a small portion of the catchment above Raniganj has received more than 10″ of rainfall while in the greater part it is between 5″ and 10″. This is shown in Fig. 5.

In order to get an idea of the distribution of daily rainfall during storm periods all occasions of heavy rainfall in five, six and seven consecutive day periods with a daily average of about 1½″ have been examined. Table 3 (printed separately) gives the rainfall spells of five day periods.

Five-day period :—There are nine spells of five-day rainfall exceeding 7.5″ and these are given in table 3. About seventy percent of the five-day storm rainfall occurs in the central three-day period. The average percentage in three consecutive days is 86 and in four consecutive days is 95. Of all the spells mentioned in the table, there was only one when the rainfall on each of the five days was 1″ or more. This was also the occasion when the highest five-day total of 11.85″ was recorded during 1891 to 1950.

Seven-day period :—65 to 70% of the 7-day rainfall occurs in three days. About 90% of the seven-day total occurs in five days.

Rainfall in the neighbourhood of the catchment and transposition of storms

The two maximum seven-day rainfall amounts in the catchment during 1891 to 1950 were during the storm period 5-12th August 1913. The total rainfall from 5th to 11th was 12.3″ and 6th to 12th was 12.2″. The track of the storm was over a very small portion of the catchment only and to the north of it. The ratio of the rainfall of the catchment to the heaviest rainfall over an equivalent area in the neighbourhood was about ·6. The following table gives the frequency distribution of the ratio of the rainfall of the catchment to the heaviest rainfall over an equivalent area for 23 storms.

Ratio	*Frequency*	*Ratio*	*Frequency*
0 — 0.4	0	0.71-0.8	7
0.41 — 0.5	4	— 0.9	7
— 0.6	5	— 1.0	3
— 0.7	3		

If the three occasions when the heaviest rainfall was over the catchment itself are excluded, 60% of the remaining occasions had a ratio less than 0.7 and 95% of the occasions less than 0.8 Besides, five of the seven occasions when the ratio was between 0.71 to 0.80 corresponded to rainfall amounts over the catchment of less than 9″. Depth-area curves for different days are given in Fig. 4.

Transposition of storms.—(i) Storm transposition is the application of a storm from one area to another

within the same meteorologically homogeneous region. It is first necessary to determine whether the storm to be transposed could have occurred in the required area. For example, cyclonic rains occurring along the coast cannot generally be transposed much inland for the storms weaken rapidly after crossing the coast. On the other hand thunderstorms which can occur almost anywhere over wide regions, can reasonably be transposed. Other kinds of storms may or may not be transposed depending upon the meteorological and topographical features. Storms in mountain region cannot be transposed.

The transposition of storms is likely to be very useful for obtaining an idea of storm rainfall in an area (*i*) when adequate rainfall data are not available for the area but data for a long period exist for another meteorologically homogenous neighbouring area and (*ii*) when rainfall data are available only for a short period for that area and the other areas in the meteorologically homogeneous region. To transfer storms from one area to another with similar rainfall data of fairly long period, requires a detailed examination of the meteorological and topographical conditions of the areas. If for a large number of years one area has been getting more heavy rainfall than the other, the transposition of a storm from the first area to the second would not be justifiable without detailed examination to determine whether the particular storm could have occurred in the second area. Even if it is found that such a storm can be transposed from the first area to the second, it has still to be examined as to whether the storm would change in magnitude. The magnitude depends upon the air movements and moisture content, the latter of which can be estimated from surface dew point temperatures. If there is a difference in orographic features or elevation the storm has to be adjusted also to the surface dew point temperatures of the area to which the storm is to be transposed. Again, the orientation and shape of the isohyetal pattern also play a significant part in determining the rainfall over the basin.

(*ii*) The main cause of heavy rainfall in the Damodar catchment and the neighbourhood is practically the same, but as mentioned in the previous paragraph during the course of sixty years (1891-1950) even on occasions when the catchment received the heaviest rainfall, there were areas in its neighbourhood which received much heavier rainfall. In this connection it may be mentioned that the topographical features and average elevation of the catchment are also different from the neighbouring areas where heavier rainfall has occurred. It would, therefore, appear that the magnitude of the storms in the neighbourhood would be affected, if transposed to the Damodar catchment. Transposition of storms is therefore not recommended for this area.

Problem maximum rainfall in the catchment

This has been estimated by a number of methods. One of them is by fitting semilogarithmic curves to 1 to seven-day frequency distribution. The probability P that rainfall exceeds x is given by

$$P = 1 - \frac{1}{\sqrt{\pi}} \int_{-\infty}^{c \log \frac{d(x+b)}{\sqrt{t^2+1}}} e^{-u^2} du$$

where b,c,d and t are derived from the first three moments of the frequency distribution. The semilogarithmic curve considered is

$$y = a\, e^{-c^2 \{\log d\,(x+b)\}^2}$$

The probable maximum rainfall amounts in one to seven days in the Damodar catchment are :

No of days	*Rainfall*	*No. of days*	*Rainfall*
1	7.5	5	17.0
2	12.0	6	17.5
3	14.0	7	18.0
4	16.0		

Out 18″ in 7 days, 15″ may occur in 4 days and 13″ in 3 days.

Discharges at Rhondia

Stream-flow records at the Anderson Weir at Rhondia about 40 miles below Raniganj on the main Damodar river, are available for the period 1934-48 have been examined. The frequency of occasions exceeding 20,000 cusecs and 200,000 cusecs are given below.

	June	*July*	*Aug.*	*Sept.*	*Oct.*	*June-Oct.*
(*i*) 20,000	42	205	319	239	81	886
Expressed as % of total number of occasions.	11	44	70	55	22	42
(*ii*) 200,000	0	2	9	3	1	15
Expressed as % of total number of occasions.	0	.44	1.98	.69	.27	.71

The only occasion in October when the discharge (525,000) exceeded 200,000 cusecs was also the highest average daily discharge in any of the months during 1934-48.

Table 4 (printed separately) gives the average daily rainfall of the catchment in cent for five days ending on the date when the average daily discharge was more than 2 lakh cusecs.

What is effective in giving high discharge at Rhondia on any date is heavy rainfall (>1″) in preceding two or three days. On all occasions the rainfall was>1″ on the preceding day and on about 70% of the number of occasions it was more than 2″. High discharge for any date is significantly influenced by rainfall on that date and the preceding date.

The regression formula between rainfall (R) of July to October and the corresponding seasonal flow (D) expressed in inches is

$$D=0.65\ R-8.68$$

From this formula,

Highest discharge (1917)=5,621,200 cusecs or 1,114,880 Acre ft.

Lowest discharge (1918)=1,794,460 cusecs or 3,559,040 Acre ft.

Discharge of the Damodar river at Rhondia on any day is very highly correlated with the following:

(*i*) Rainfall of preceding day (R_{-1}) .73
(*ii*) Rainfall of preceding two days ($R_{-1}+R_{-2}$) .80
(*iii*) Rainfall of preceding day and discharge of preceding day. .82

The Regression formulae are :—

(*i*) $D=0.3979\ D_{-1}+5.7953\ R_{-1}+0.4275$ (D in 10000 cusecs) multiple C.C. .82
(*ii*) $D=4.34\ (R_{-1}+R_{-2})+0.9703$ (D in 10000 cusecs) .81
(*iii*) $D=71.70\ R_{-1}+14.6757$ (D in 1000 cusecs).

MAYURAKSHI CATCHMENT

This catchment is just above the Damodar and has an area of about 720 sq. miles up to the Massenjor Dam site. The annual rainfall of this catchment varies from about 50″ to 58″ with a mean value of 52″ for the catchment. The catchment and the insohyetal lines are shown in Fig. 6. 81% and 87% of the annual rainfall is received during the two periods June-September and June-October respectively.

	June	*July*	*Aug.*	*Sept.*	*Oct.*	*June-Oct*
Mean rainfall (inches)	8.62	13.14	12.15	8.48	3.50	45.88
Standard deviation	4.79	3.76	3.93	3.41	3.45	8.56
Coefficient of variation%	56	29	32	40	99	19
Highest	24.22	24.66	23.83	17.41	15.84	65.44
% of mean	281	188	196	205	453	143
Lowest	1.00	4.22	6.21	2.91	0	31.88
% of mean	12	32	51	34	0	69

While large variations in the monthly rainfall are likely, the highest and lowest rainfall for the monsoon season have not exceeded 1½ times the normal or fallen to less than two third of the normal during a period of 60 years. The frequency distribution of June to October rainfall is.

Range (inches	*Frequency*	*Range (inches)*	*Frequency*
31.01-35	7	51.01-55	11
-39	8	-59	6
-43	10	-63	2
-47	9	-67	1
-51	6		

$g_1=0.144$ S.E.$(g_1)=.309$ $g_2=-.9671$ S.E.$(g_2)=.608$
The distribution is normal.

The decade averages of June to October are as below.

Decade		*Decade*	
1891-1900	45.38	1921-1930	45.60
- 10	41.68	- 40	45.02
- 20	48.54	- 50	49.07

The decade mean 1900-1909 (41.35) shows the highest difference (4.53″) from the 60 year mean. This difference is not significant satistically.

The equations for trend are :—

$$R=45.88+0.08(x-29.5)$$
$$R=46.42+.08x-.0018+x^2$$

None of these is significant. An examination of June to October rainfall data shows that rainfall will lie within ± 20% of normal ion about 67% of the years. Frequency distribution of daily rainfell is given below.

Range (cents)	*Frequency in 60 years*	*Range cents)*	*Frequency in 60 years*
1- 20	2669	201-300	127
21- 40	1307	-400	22
- 60	748	-500	4
- 80	504	-600	2
-100	308	-700	0
-200	526	-800	2

Similar frequency distributions of rainfall up to seven consecutive days have been prepared. All these have been fitted by semilogarithmic curves to find the probability of different amounts of rainfall. These are shown in Fig. 7 and 8.

Heavy rainfall over catchment

The average number of occasions during the monsoon season when mean daily rainfall exceeds 2″ is 2.6. The maximum recorded on a single day was 7.73″. Details of the first and second occasions of heavy rainfall up to 7 days are given in the table below.

	Date	*Amount in inches*	*Date*	*Amount in inches*
One day	13 Aug. 1935	7.73	9 Aug. 1942	7.29
Two days	12 & 13 Aug. 1935	10.98	9 & 10 Aug. 1942	9.86
Three days	12 to 14 Aug. 1935	12.34	8 to 10 Aug. 1942	11.01
Four days	12 to 15 Aug. 1935.	13.84	12 to 15 June 1911.	12.81
Five days	11 to 15 Aug. 1935	14.74	11 to 15 June 1911	14.68
Six days	11 to 16 Aug. 1935	14.93	10 to 15 Aug. 1935	14.91
Seven days	9 to 15 Aug. 1935.	16.10	11 to 17 June 1911.	15.94

Monthly Rainfall and Discharge of Mayurakshi River

Monthly volumes of discharge of river Mayurakshi at Messanjore for the monsoon season June to October are available from 1946. These are given below. These were correlated with the corresponding monthly rainfall of the Mayurakshi. The C.C. is 0.78. This is highly significant at even 1 per cent level of significance. The regression equation is :—

$$Y = .015\ x - .019$$

where Y is discharge in million acre feet and x is rainfall in inches.

Monthly volumes of discharge of river Mayurakshi at Messanjore for different years : (expressed in million acre feet).

Month	1946	1947	1948	1949	1950
June	0.069	0.017	0.032	0.108	0.289
July	0.140	0.188	0.144	0.275	0.245
August	0.160	0.224	0.185	0.363	0.277
September	0.196	0.133	0.102	0.176	0.1133
October	0.167	0.064	0.105	0.053	0.022

(Taken from the Government of Bengal Annual Report of the River Research Institute, West Bengal 1951, Publication No. 7, 1951).

Comparison between Mayurakshi and Damodar Catchments

The Mayurakshi Catchment is immediately to the northeast of the Damodar Catchment, its area being only a tenth of the latter Catchment.

Seasonal Rainfall (*a*) The average seasonal rainfall (June to October) of Damodar Catchment is 45.42″ with a standard deviation of 7.23″ and coefficient of variation of 16 per cent while that of the Mayurakshi Catchment is 45.88″, slightly higher by about ½″, with a higher standard deviation of 8.56″ and coefficent of variation of 19 per cent. The variability is slightly higher over the Mayurakshi Catchment.

(*b*) June to October rainfall accounts for 88 per cent of the annual in the case of both the catchments.

(*c*) The seasonal rainfall of Damodar was correlated with the corresponding rainfall of Mayurakshi based on data for the years 1891 to 1950. The C.C. works out to +0.71, which is very highly significant even at 1 per cent level of significance. This suggests that good seasonal rainfall in the Damodar generally corresponds to good seasonal rainfall over Mayurakshi Catchment.

(*d*) The distribution of monsoon rainfall is normal in the case of both the catchments.

Heavy rainfall (*a*) The heaviest rainfall in the two catchments in 1 to 7 days is as follows :—

	1 day	2 days	3days	4 days	5 days	6 days	7 days
Mayurakshi	7.73	10.98	12.24	13.84	14.74	14.93	16.10
Damodar	4.91	7.50	9.21	10.63	11.85	12.19	12.32
$\frac{May.}{Dam.} \times 100$	157	146	133	130	125	113	113

(*b*) The highest rainfall recorded at any station in the Damodar Catchment in a day is 12.8″ at Kodarma in August 1917. The corresponding figure is 10.51″ at Naya Dumka in September 1935.

(*c*) All occasions of three-day heavy rainfall (1″ or more on each day) over Mayurakshi were correlated with the corresponding rainfall of Damodar. The C.C. is +0.57 suggesting very high association between the two.

(*d*) Similarly all occasions of three day heavy rainfall (1″ or more on each day) over Damodar were correlated with the corresponding rainfall over Mayurakshi. The C.C. is +0.45.

There were only four occasions when the region of the heaviest rainfall over an equivalent area was to be east or northeast and on these occasions good rainfall occurred also over Mayurakshi Catchment.

(*a*) The C.C. between rainfall in the Damodar Catchment and Mayurakshi Catchment for the occasions of storm rainfall is +0.63 which is highly significant even at 1 per cent level of significance.

(*b*) The C.C. between rainfall over Mayurakshi Catchment and the rainfall over the area of heaviest rainfall was +0.50.

The above would suggest close connection between rainfall over Mayurakshi catchment and neighbourhood.

Although the rainfall in the two catchments is significantly correlated, yet it does not necessarily imply that the same amounts of rainfall could occur over both the areas. The maximum probable precipitation likely in the two catchments is as follows :—

Days	*Mayurakshi*	*Damodar*
One	11.5	7.5
Two	16.0	12
Three	19.0	14
Four	21.0	16
Five	22	17

Reference has been earlier to the question of transposition of storms from one area to another. For reasons mentioned therein, we cannot transpose a storm which had occurred over the Damodar Catchment or in its neighbourhood to the Mayurakshi Catchment and vice-versa.

References

1. Pramanik, S. K. and K. N. Rao 1953. Hydrometeorology of the Damodar Catchment. Memoirs of the India Meteorological Department, Vol. XXIX, Part VI.
2. Pramanik, S. K. and K. N. Rao. 1954. Hydrometeorology of the Mayurakshi Catchment. Memoirs of the India Meteorological Department, Vol. XXX, Part II.

TABLE 3

Daily rainfall in cents on occasions of total rainfall in 5 days exceeding 7.5 inches.

		Five-day total rainfall (Cents.)	*Daily rainfall on the date in col. 1 and following four days.*					*Maximum 3-day total.*	*Percent. for 3 days.*	*Per cent for 4 days*
			On Date	1	2	3	4			
1898 June	15	804	6	13	212	306	267	785	98	99
	16	801	13	212	306	267	3	785	98	100
	17	789	212	306	267	3	1	785	99	100
1928 June	15	766	114	167	86	186	204	476	62	85
1897 July	11	833	18	125	241	317	132	690	83	98
	12	874	125	241	317	132	59	690	79	93
	13	795	241	317	132	59	46	690	87	94
1917 July	29	897	75	139	204	283	196	683	76	92
	30	859	139	204	283	196	37	683	80	99
1943 July	13	956	46	70	100	423	317	840	88	93
	14	976	70	100	423	317	66	840	86	93
	15	1009	100	423	317	66	103	840	83	90
	16	994	423	317	66	103	85	806	81	90
1913 Aug.	4	915	0	34	147	300	434	881	96	100
	5	1102	34	147	300	434	187	921	84	97
	6	1185	147	300	434	187	117	921	78	90
	7	1051	300	434	187	117	13	921	88	99
	8	772	434	187	117	13	21	739	96	97
1935 Aug.	8	928	88	48	82	219	491	792	85	91
	9	1051	48	82	219	491	211	921	98	99
	10	1073	82	219	491	211	70	921	86	93
	11	1066	219	491	211	70	75	921	86	93
	12	869	491	211	70	75	23	772	89	97
1942 Aug.	6	765	56	96	95	300	218	613	80	93
	7	754	96	95	300	218	45	613	81	94
1916 Sept.	21	759	80	223	376	52	28	679	90	96
Average		909	141	200	230	206	133	..	86	95
Average (if occasions with 10" or more only are considered.)		1043	133	299	308	197	111	..	..	..

TABLE 4

		Days					Average daily discharge in cusecs on the last date mentioned in col. 1
		1	2	3	4	5	
August	1935, 8-12	88	48	82	219	49	422500
September	1935, 18-22	18	12	56	129	165	204420
July	1937, 27-31	103	55	90	228	125	202392
	1939, July 31-Aug.4	74	120	67	101	240	258500
	1939, Aug-1-Aug.5	120	67	101	240	85	208000
August	1940, 25-29	27	46	184	272	81	266500
October	1941, 6-10	0	7	113	323	254	521500
August	1942, 6-10	56	96	95	300	218	375500
	7-11	96	95	300	218	45	268600
August	1945, 1-5	78	77	84	341	211	252262
September	1946, 14-18	23	53	60	255	188	313738
	1947, July 29-Aug. 2	10	66	190	167	53	200275
	1947, Aug. 31-Sept. 4	42	20	47	220	176	259567
August	1948, 2-6	50	91	138	177	31	239671
	Average	56	61	115	221	169	
	Highest	120	120	300	323	491	
	Lowest	0	7	47	101	31	
	Number of occasions exceeding .75"	5	5	11	14	11	
	1"	2	1	6	14	9	
	2"	0	0	1	10	4	
	3"	0	0	0	1	1	

Facing page 28

FIG. 1

HEAVIEST RAINFALL IN A DAY IN THE DAMODAR CATCHMENT.
FIG. 5.

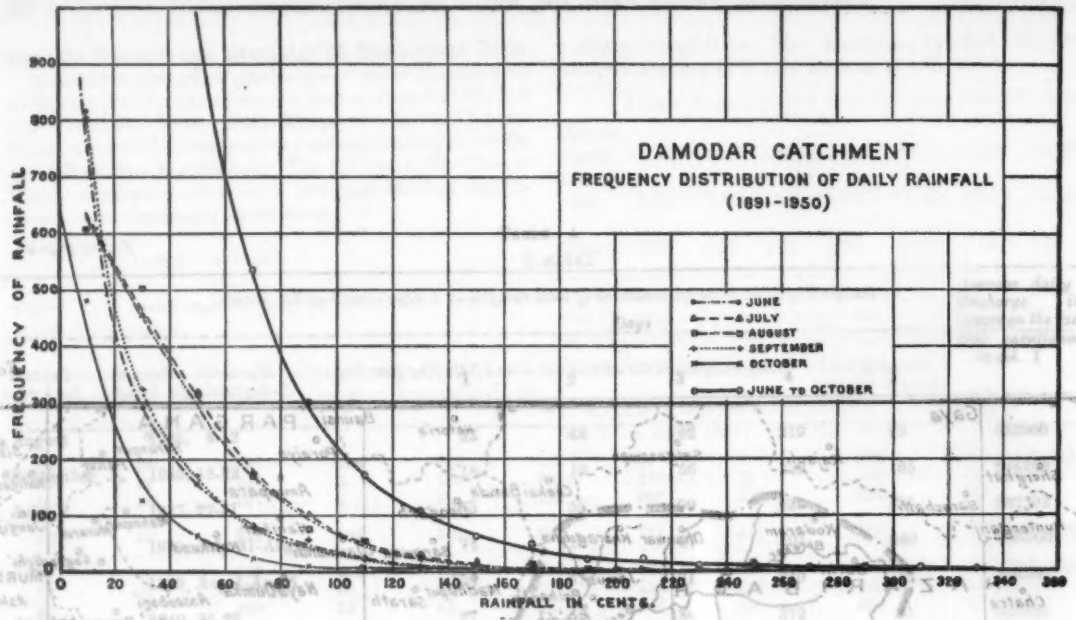

DAMODAR CATCHMENT
FREQUENCY DISTRIBUTION OF DAILY RAINFALL
(1891-1950)
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
JUNE TO OCTOBER
FREQUENCY OF RAINFALL
RAINFALL IN CENTS.

FIG. 2.

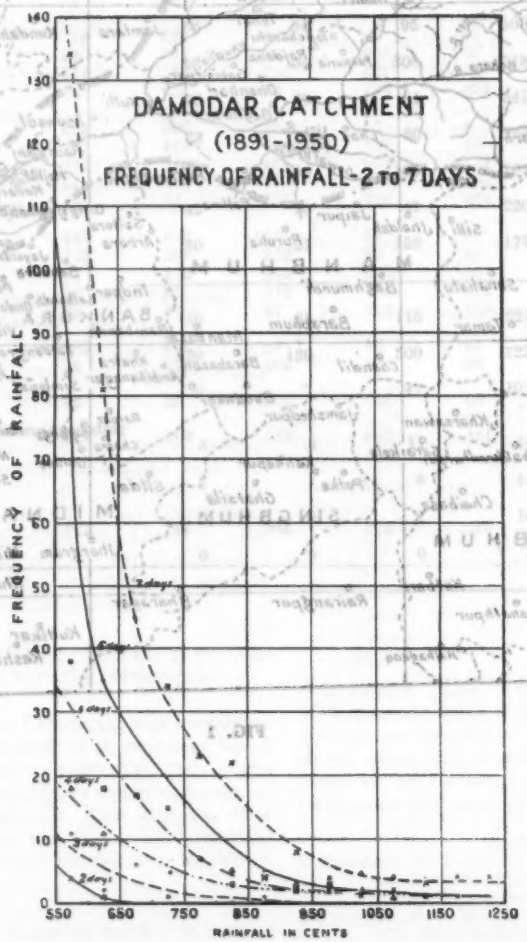

DAMODAR CATCHMENT
(1891-1950)
FREQUENCY OF RAINFALL-2 TO 7 DAYS
FREQUENCY OF RAINFALL
RAINFALL IN CENTS

FIG. 3.

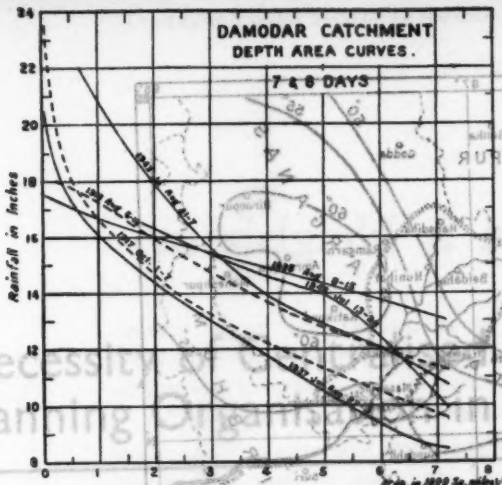


FIG. 4a.

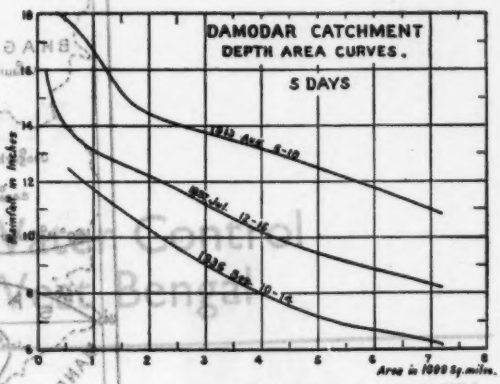


FIG. 4 b.

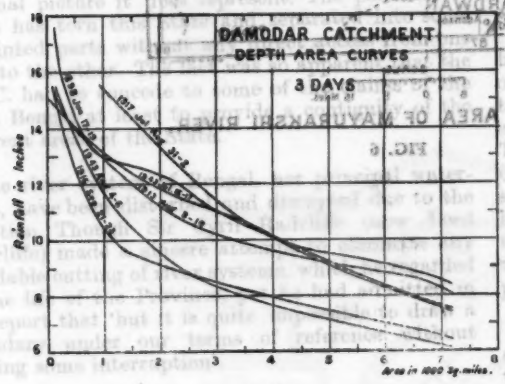


FIG. 4 c.

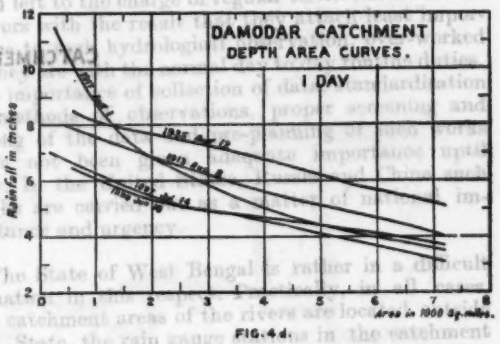
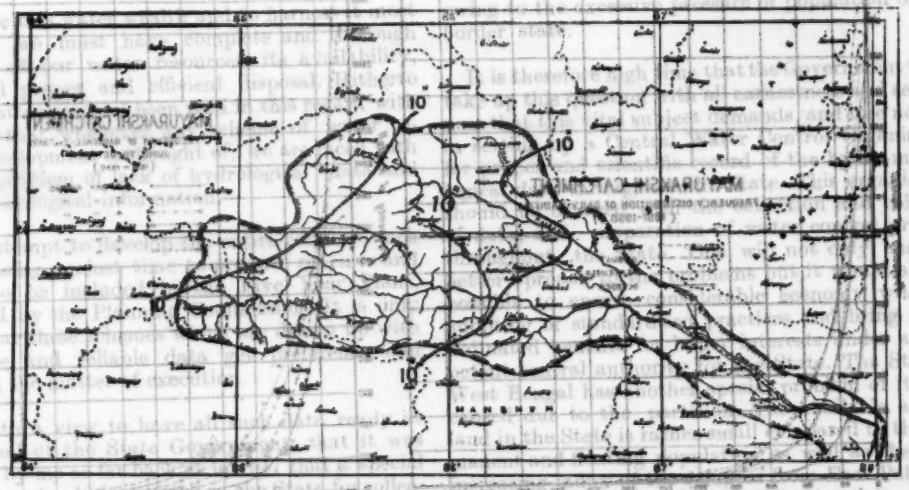


FIG. 4 d.



HEAVIEST RAINFALL IN 24 HRS. IN THE DAMODAR CATCHMENT.

FIG. 5.

G.P.I.-P. POONA, 22.

CATCHMENT AREA OF MAYURAKSHI RIVER.

FIG. 6

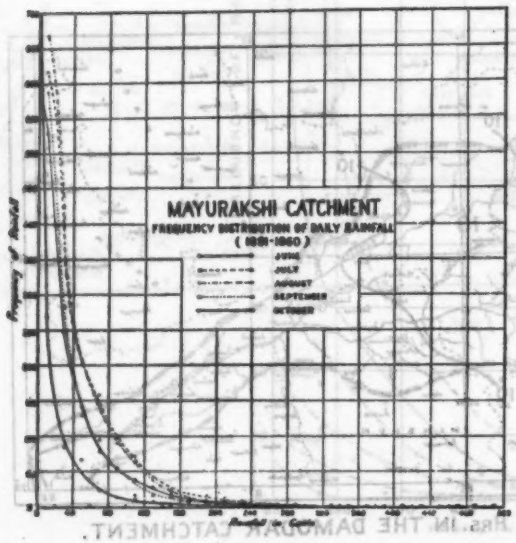


FIG. 7

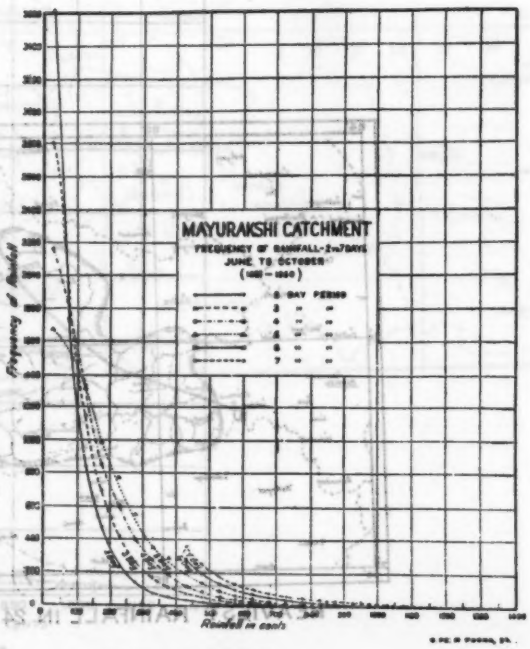


FIG. 8

Necessity of Centralised Water Control Planning Organisation in West Bengal

D. MOOKERJEA

IF we look at the map of West Bengal, what a dismal picture it does represent. The partition of India has torn this State and separated into some disjointed parts without any direct access from one part to the other. The fact was so apparent that the S.R.C. had to concede to some of the claims of the West Bengal at least to provide a contiguity of the different areas of the State.

The river system of Bengal, her principal waterways, have been disturbed and disrupted due to the partition. Though Sir Cyril Radcliffe (now Lord Radcliffe) made a sincere attempt to eliminate any avoidable cutting of river systems, which he regarded as the life of the Province, yet he had admitted in his report that 'but it is quite impossible to draw a boundary under our terms of reference without causing some interruption'.

'Water' is the potential wealth of the State and if the water can be suitably utilised for generation of power, for irrigating vast cultivable lands, the national income can be increased tremendously, thereby raising the standard of living of our countrymen which is the sole objective of the National Plan drawn up under the guidance of our Prime Minister.

To utilise this water wealth and to harness it most effectively, we must have complete and thorough knowledge of our water resources, its availability, utility and proper and efficient disposal. Hitherto not much attention had been paid in this regard with the result that whenever any scheme of water resources development is thought of, we are faced with the same problem of lack of hydrological data and even meteorological information.

In an attempt to develop the entire country, each state is racing against time to produce schemes and projects to be included in the Five Year Plans, formulated by the Planning Commission. It is only natural that these schemes which are drawn up with dependable and reliable data get preference and priority in the matter of execution.

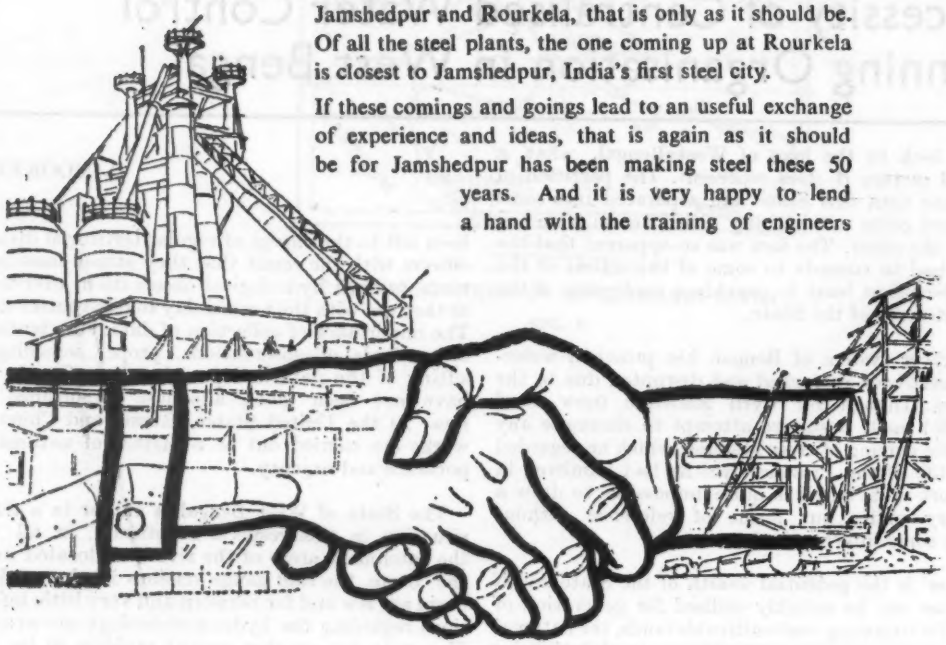
It is with a view to have all such data ready at the disposal of the State Government, that it was suggested by me as far back as in 1947 that a special organisation should be created in the State for collection of data. At the present moment such work has been left to the charge of regular territorial divisional officers with the result that they attach least importance to such hydrological observation, over-worked as they are with the normal day to day routine duties. The importance of collection of data, standardisation of methods of observations, proper screening and sifting of the data and pre-planning of such works have not been given adequate importance uptil now. In the United States, Russia and China such works are carried out as a matter of national importance and urgency.

The State of West Bengal is rather in a difficult situation in this respect. Practically, in all cases, the catchment areas of the rivers are located outside the State, the rain gauge stations in the catchment basin are few and far between and very little informations regarding the hydro-meteorology are available. The state has another special problem in its being located at the mouth of the Gangetic delta. Tides in the outfall of the rivers play a dominant role in controlling the drainage of the basin especially from the areas which have been reclaimed prematurely, owing to the excessive pressure of population on this border state.

It is therefore high time that the Government would take up this question with all earnestness and seriousness that this vital subject demands, and lose no time in setting up a Central Water Control Organisation for proper and scientific record of the hydro-meterological data throughout the State. This organisation should be charged with the collection and collation of data, and preparation of water control projects throughout the State. This will not only ensure a better aproach to the problems but it would also be possible to ensure considerable economy with the adopting of standardised practices and bring in coordinated benefits for larger interests under a competent central authority for the State. The State of West Bengal has another special problem of its own caused due to the partition. The available area of land in the State is rather small compared to the permanent and floating population as well as the ever-increasing influx of the refugees from East Pakistan.

[*Continued on page* 40

From a Neighbour



If there is a lot of comings and goings between Jamshedpur and Rourkela, that is only as it should be. Of all the steel plants, the one coming up at Rourkela is closest to Jamshedpur, India's first steel city.

If these comings and goings lead to an useful exchange of experience and ideas, that is again as it should be for Jamshedpur has been making steel these 50 years. And it is very happy to lend a hand with the training of engineers and technicians for Rourkela. There are nearly 150 of them at Jamshedpur—from key personnel to artisans.

Strengthening these ties of friendship are the surprisingly large number of old Jamshedpur faces that one sees at Rourkela. To them and their colleagues, Jamshedpur sends neighbourly greetings and good wishes.

Good Wishes to Rourkela

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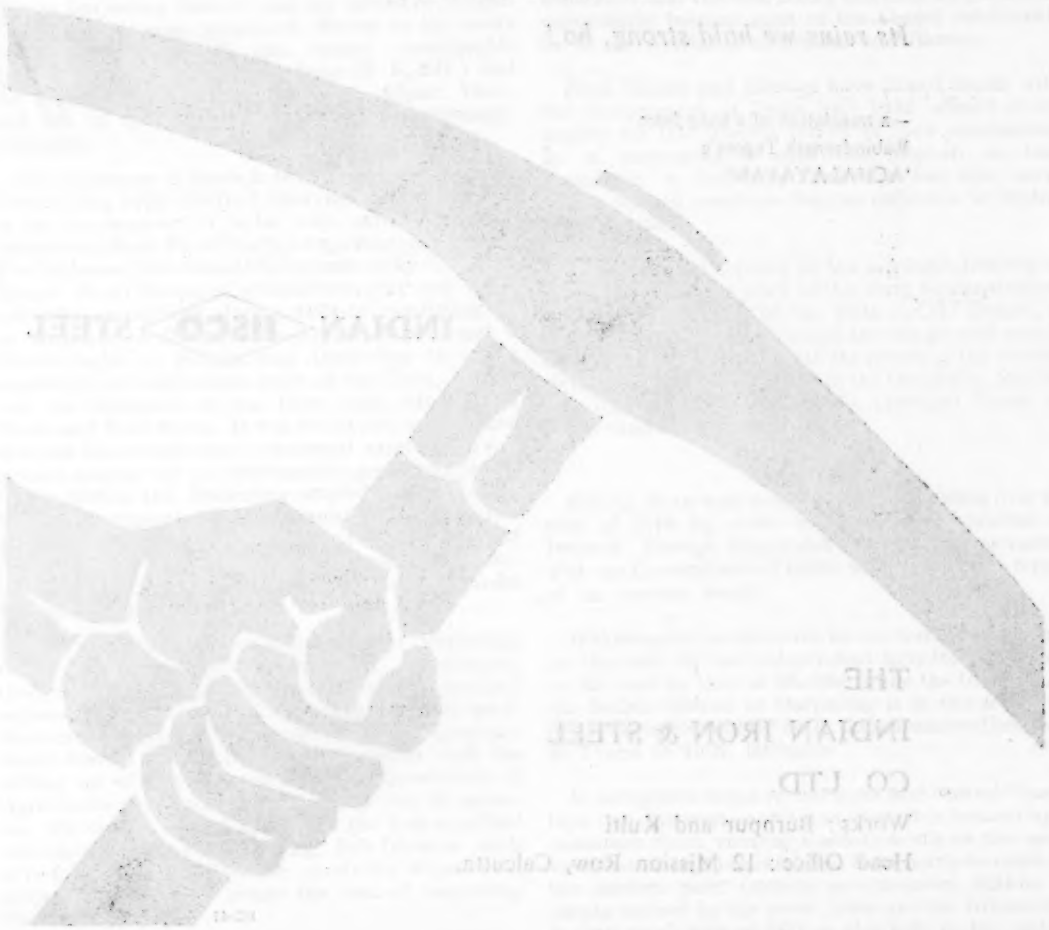
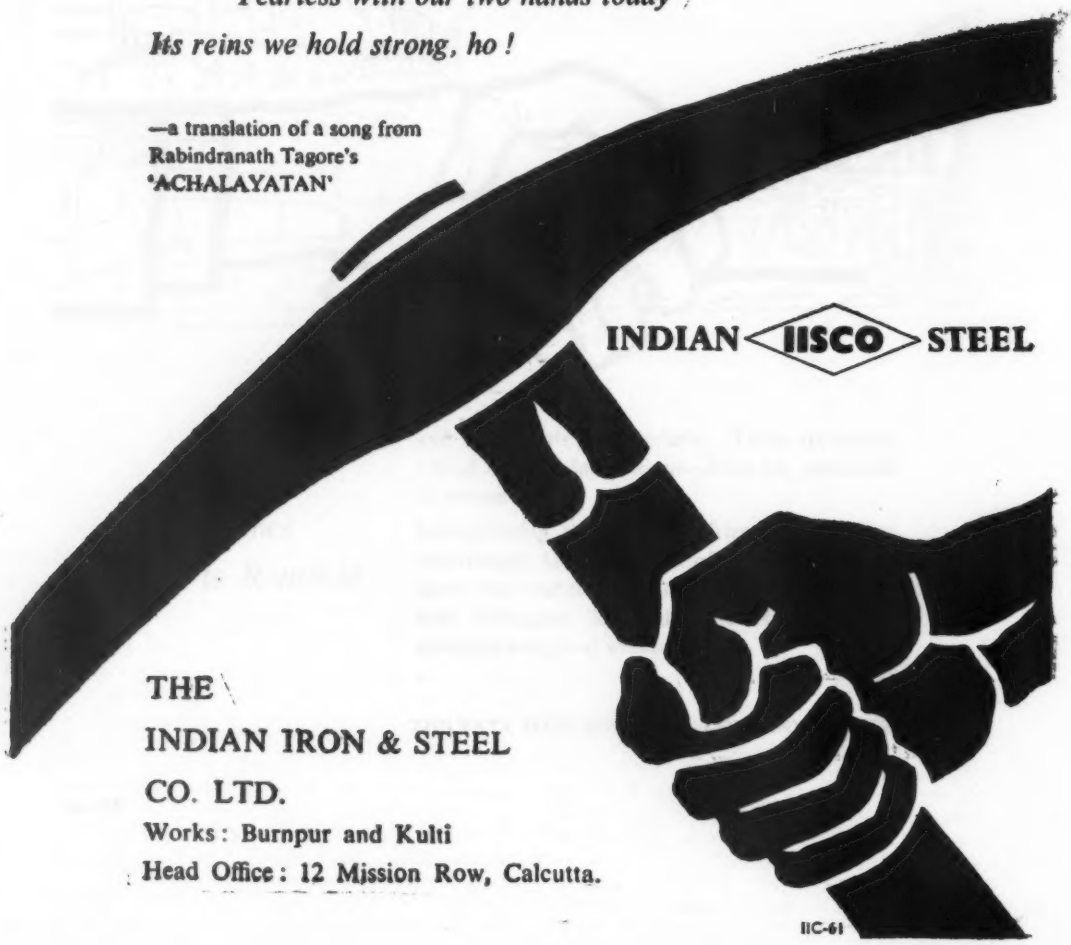
Subject II

Flood Control, Soil Erosion & Silt Problems & Role of Forestry



The hard iron lay dead in slumber deep
And we stirred it to life, ho !
In the dark depths of a million years it lay hid
And we stirred it to life, ho !
Tamed by our strong hands
It sings to the tune we call.
Its silence of long years have we broken, ho !
The dead doth stir with new life today
And rushes forth the wide world to conquer.
Fearless with our two hands today
Its reins we hold strong, ho !

—a translation of a song from
Rabindranath Tagore's
'ACHALAYATAN'



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IIC-61

Geological Aspects of North Bengal Floods

By G. N. DUTT

The object of this paper is to describe the geological aspects of floods in North Bengal which in the past few years had eroded valuable land and tea-gardens, and had damaged private and public property.

Most of the floods occurred in the Tista and its tributaries originating in the Kalimpong Sub-Division of the Darjeeling district, and the towns of Siliguri and Jalpaiguri were inundated. Floods in the rivers originating in Bhutan also caused considerable damage to the Assam link railway (N. E. Rly.) and the highways between Siliguri and Alipur Duar, and life in Cooch Behar town was particularly disrupted.

The recurrence of floods in the Tista, Jaldhaka and Torsa during 1948, 1950 and 1954 caused great concern to the Government of India, who have set up the Central and State Flood Control Organisations in 1954. The Technical Sub-Committee sponsored by the North Bengal Flood Enquiry Committee sent out three scientific expeditions during 1954-55, consisting of an Engineer, a Geologist, a Forest Expert and a Meteorologist to Sikkim and Darjeeling to study separately the catchment areas of the Tista, Rangit and the tributaries of the Tista—Lish, Gish, Chel, Neora and Relli rivers. It was found out in each case that the floods were due to abnormal rainfall and soil erosion arising out of unfavourable geological structure in Sikkim and Darjeeling coupled with primitive land management and unscientific forestry. The eroded soil has raised the bed of rivers in the plains of North Bengal, and consequently a prolonged or concentrated rainfall in the catchment caused the rivers to overflow their banks.

An organisation has now been set up at Darjeeling under the Irrigation & Waterways Directorate, Government of West Bengal, to draw up a detailed scheme of soil conservation and preparations of specifications and estimation of cost of certain proposed check dams in Sikkim State. Simultaneous with the setting up of this organisation, the Directorate of Agriculture took upon themselves the task of assessing the extent of soil erosion in the Lish and Chel catchments of the Kalimpong Sub-Division with a view to restrict cultivation on stabler slopes with proper terracing and assess the cost of improving the land.

For many taking part in this symposium, it will be news that schemes of soil conservation on such large scale have been taken up in this country for the first time in West Bengal, and it has to be admitted by all concerned that the task facing this country is colossal, particularly because most of the abused catchments lie in the territories of Sikkim and Bhutan.

Both Sikkim and Bhutan have joined hands with the Government of India and have offered every facility for the detailed survey of their catchments. It is heartening to note that Bhutan, so long considered a forbidden territory, has now many Indian-trained observers for the collection of hydrological data.

The writer was deputed by the Geological Survey of India to accompany each of the three reconnaissance parties to catchments of the Tista and the Rangit, in Sikkim & Darjeeling Himalaya and the present article attempts to deal briefly with the nature of the various rivers and their catchments in the Darjeeling, Sikkim and Bhutan Himalaya and the principal causes of floods and their remedy.

SIKKIM

Sikkim is an autonomous State, extending over an area of 2818 sq. miles with the administration of Defence, Foreign Affairs and Communications vested with the Government of India, according to the terms of an ancient treaty.

It is bounded on the north by the territory of Tibet, on the west by the independent kingdom of Nepal, on the east by that of Bhutan, while the territory of the Indian district of Darjeeling is in the south. It lies between 88° and 88° 54′E. Longitude and between 27°7′ and 28°10′N. latitudes.

It occupies a recess in the inner and central Himalaya ; on the west, north and east, it is bouned by a mountain chain, running south-to-north on the west, west-to-east on the north, and from north-to-south in the eastern part. Largely mountainous, Sikkim is deeply incised by the river Tista and its tributaries. A very small area of Sikkim also falls in the watershed of the Jaldhaka river. While three sides of

Sikkim are surrounded by mountain chains, most of its southern boundary is covered by the valley of Great Rangit river, the principal tributary of the Tista. The lowest elevation in the State is 746 ft. above mean sea level, occurring at the confluence of the Tista with the Rangit, and the highest is the towering mountain of Kanchanjungha (28,146 ft.).

The line of permanent snow lies between 13,000 and 16,000 ft., depending upon the topographical aspects. At altitudes between the snow line and 12,000 ft., the rainfall is considerably lower than in the region below, with the result that the flora is mainly of the high Alpine type. Lower down, on account of heavy rainfall ranging up to 200 inches per annum, lies a dense semi-tropical to Alpine forest. The flora at lesser elevations are generally of the type induced by tropical monsoon conditions.

The latest census figures of 1951 report the population of Sikkim to be at 1,37,725 ; this is distributed at the rate of 50 per square mile, compared with 16 for Bhutan and 371 for the the Darjeeling district. Most of the population belong to the Nepalese settlers, who began to inhabit this country since the 19th century. Tibetan settlers and Lepchas, the original inhabitants of Sikkim, live mainly at altitudes above 6,000 ft., and are found almost exclusively in the valley of the Tista and its tributaries, north of Dikchu.

With the exception of a few engaged in trade, construction work and services, the rest of the population owe their livelihood to agriculture. The main produce is millet, wheat and maize ; paddy is grown in fields with continuous supply of water.

There is at present an Indian operated National Highway linking its capital Gangtok with Siliguri Railway station on the North-Eastern railway. There also exist roads suitable for jeep between Melli, Nayabazar, Namchi and Gangtok. Now operated only as fair-weather roads, the Seven Year Development Plan of Sikkim (now in operation), envisages the widening and betterment of these roads to suit heavy vehicular traffic.

Meterological Aspects

Meterological stations are very few in this State, compared to Indian standards, with the result that reliable data are not always forthcoming.

Except for a few winter showers during the end of December and the middle of January, the period from the middle of October to the end of March is comparatively drier than during the rest of the period. Thunderstorms, accompanied by hails, begin from the month of April, but the wettest months range from June to September. The precipitation during the latter period, which occurs continuously for several days together, is the principal factor causing floods in the plains of north Bengal. Sudden and continuous rainy weather is also responsible for causing of landslides of huge dimensions in the catchment of the Tista, which eventually adds to the flood problem. There is no doubt that a part of the monsoon current enters into the State through the valley of the Tista and passes through a considerable stretch of territory before the clouds get rid of their moisture by striking against towering mountains. Consequently, an area far to the north is likely to receive more rainfall than the southernmost areas of the State.

Drainage System

Tista river

The river Tista, about 145 ft. wide at Singtam, has a bed slope varying from 87 ft. to 184 ft. per mile between Singtam and Chungthang.

Upstream of Chungthang, the Tista bifurcates into two tributaries, the Lachen Chu on the west and Lachungchu on the east. The bed slope of Lachen-Chu varies between 128 ft. and 430 ft. per mile, while that of Lachungchu ranges between 285 ft. and 385 ft. per mile.

Cursory estimates of discharge of the Tista and its principal tributaries were obtained at the time of the reconnaissance survey during September and October, 1954. The Tista recorded 25,600 cusecs at 13¾ milestone north of Dikchu. At Tung it was 9,000 cusecs, at Chungthang 6,500 cusecs, and at Makha 11,700 cusecs. The discharge of some of its tributaries taken during this period is as follows :—

	Cusecs
(1) Rangni Chu near Singtam	500
(2) Dikchu a mile 13 from Gangtok	500
(3) Talung Chu at mile 22 from Gangtok	1,000
(4) Chakung Chu at mile 32 from Gangtok	2,000

Those of the principal tributaries of river Lachen are given below :—

	Cusecs
(1) Yel Chu at mile 39½	200
(2) Rabom Chu at mile 40¾	200
(3) Tarum Chu at mile 43¼	250
(4) Zemu Chu at mile 50½	1,000

The river Lachung receives a somewhat lesser amount of discharge as shown below :—

	Cusecs
(1) Tibik Chu at mile 40½	200
(2) Sargophui Chu at mile 45¾	100
(3) Pao Chuthang at mile 65½	42

Rangit river

In contrast with the Tista, the course of its principal tributary, Rangit, is more sinuous. In dry months its water becomes a beautiful shade of green, as most of it is derived from springs instead of glaciers.

The slope of the river between Singla Bazar and Kalet Chhu confluence is 43 ft. per mile along a length of 23 miles. A few discharge observations, taken during the month of April 1955, are given below :—

	Cusecs
(1) Champa Bridge site (near Tista-Rangit confluence)	600
(2) Ralu Khola	1,500
(3) Below Kalet Chhu	950
(4) Ligship Bridge	600

The dischrage of some of the important tributaries of the Rangit is shown below :—

	Cusecs
(1) Chota Rangit river	100
(2) Rammam river	300
(3) Kalet Nadi	100
(4) Rathong Chhu at the wooden bridge	250
(5) Rimbi Chhu	200

Catchment area of rivers in Darjeeling and Sikkim

Name of the river	*Area drained (sq. miles)*	*Area of permanent snow (sq. miles)*
*Tista	2,610	275
Rangit	820	30
Mahananda	160	
Relli	64	
Gish	62	
Neora	52	
Chel	40	
Lish	19	

* The area includes the catchments of Reli, Gish, Neora, Chel and Lish.

The total area of the catchment of the Rangit in Sikkim State is 622 sq. miles and that of the Jaldhaka in Sikkim is 29 sq. miles. The total ar a of the catchment of the Tista in this State, minus the ar:a drained by the Rangit, is 2,177 sq. miles.

Record of Recent Floods and Casualties

In Lachen river, records indicate that a severe flood occurred in 1948 as a result of the bursting of the dam caused by the Fim Chhu rock-slide, a few miles upstream of Chungthang. The highest reco ded flood level of the Tista at the Indian Observation Station, Tista Bridge, is 686 ft. (above M.S.L.) on the 12th June, 1950, which was said to have been caused by the bursting of the glacial lake of Sebu Chho at the head of the Lachung river. This had caused considerable damage in the plains of the Jalpaiguri district.

The heaviest flood occurred in the Tista during the monsoon of 1954. An abnormal rainfall increased the runoff abruptly and started landslides in unstable regions. It later took toll of several lives in Sikkim. Subsequent to the failure of the Moraine dam at Sebu Chho the waterlevel upstream rose up to a height of about 30 ft. above the normal level. Shortly after midnight, this rushing water took a sudden southwesterly course killing instantly six people who were attempting to flee west towards the hill. Ten harts were destroyed and 60 heads of cattle and ponies could not be accounted for. A small lake was formed just south of 8th milestone near the Chhachhu hot spring. This lake burst soon after and laid waste the western portion of Lachung village. The subsidiary damburst caused a rise of about 60 ft. in this river near Chungthang.

In Western Sikkim, the Bhondi Khola landslide, which occurred on the 26th September, 1952, killed two and injured several people, while the Ligship mud-flow in S ptember, 1954, killed a woman with her baby-in-arms during sleep at night. Several other slides near Kewzing in 1954 caused many casualties.

The plains of North Bengal suffered most during the 1954 floods. The first casualty occurred at the Panchanai bridge. Road bridges on the National Highway No. 31, over the Chel, Mal, Sukhajhora, Neora, Dimdima, Char Torsa, were completely destroyed. The towns most affected were Siliguri, Jalpaiguri, Cooch Behar, Alipur Duar and Mathabhanga. Damages to railroad and other public and private property were also considerable.

BHUTAN

The latest information on Bhutan, about independent kingdom, shows that its area is approximately 18,000 sq. miles. On account of lack of census figures, the latest population figures have roughly been computed at 300,000, which are mostly of Tibetan affinities. People of Nepalese origin, who are known as sturdy and methodical cultivators, are allowed to inhabit the country in the foot-hills as far east as the Amo-chu river.

The boundary of this State coincides with nearly 200 miles of the Indian frontier bordering the States of West Bengal and Assam.

The topography presents a succession of lofty and rugged mountain ranges generally aligned from north to south.

The principal mountain ranges, proceeding from west to east, are : Masong-chung-dong between the rivers Amo-chu and Wang-chu ; the Dokyong-la between Wang-chu and Ma-chu ; the black mountain range between Ma-chu and the Manas ; and on the extreme east, the Tawang range.

As in the adjoining region of the Himalayas on the west, the territory of Bhutan can be geographically divided into three zones.

Comprising the outer hill ranges and the hot humid plains, the outermost tract adjoining the plains of India is on the average 30 miles broad. Here most of the moisture laiden winds coming from the Bay of Bengal is precipitated; as a result heavy rainfall between 200 and 300 inches per annum is often recorded.

The central tract, comprising the inner Himalayas, ranges up to a width of 40 miles and covers altitudes varying from 3,500 to 10,000 ft. above sea level. The slopes of the hills are gentler and includes the fertile valleys of the Paro, Ha, and Punakha ; Incidentally these valleys support the bulk of population in Bhutan. The rainfall in the central region is moderate varying between 40" and 60" per annum. Generally speaking, the elevation of the outer ranges in eastern Bhutan is lower than the corresponding territory to the west and the eastern territory is also a region of heavy precipitation. Consequently, the monsoon travels up the valley of the Kuru-chu as far as the snowy range.

The third and the northernmost tract of Bhutan occupies rugged mountains and snowy ranges upto an elevation of 24,000 ft. Largely uninhabited, there are many Alpine valleys between altitudes of 12,000 ft. and 18,000 ft. which are utilised for the grazing of cattle.

Rivers

All the rivers having their source in Bhutan empty into the Brahmaputra, the largest being the Manas. This has two tributaries—(1) Kuru-chu or Lhobrak, and (2) Dangme-chu. The Amo-chu which is known as Torsa in India flows down the Chumbi valley between Bhutan and Sikkim in its upper reaches. The Wang-chu or Raidak drains the Ha, Paro and Trashichod-zong valleys. The Sankosh, known in its upper reaches as the Ma-chu, flows through the Punakha valley.

The Himalayan area drained by the rivers Jaldhaka, Diana, Alaikuri, Torsa, Raidak and Sankosh are tabulated area-wise in the following table :—

Name of the river	*Himalayan area drained in sq.ms.*	*Area of permanent snow. (sq. miles)*
Sankosh	3,740	60*
Raidak	1,750	28
Torsa	1,400	32
Jaldhaka	280	
Diana	116	
Alaikuri	100	

* Measured from the quarter-inch Survery of India reconnaissance map, this figure seems to be on the lower side.

Climate

On account of variations in altitude, the lower valleys of Bhutan are extremely hot and saturated with moisture. The central region is climatically more diverse containing hot valleys and cool mountain slopes. The northernmost region is afflicted with frost and ice and enjoys an Alpine climate.

The composition of the forests is much similar to that of Sikkim ; apart from rhinoceros and elephants there is also a marked faunal similarity with Sikkim.

GEOLOGICAL 'HISTORY' OF NORTH BENGAL, SIKKIM AND BHUTAN

The geology of the greater part of North Bengal consists of Older and Newer alluvium of the Tista and other rivers including the Jaldhaka and its tributaries.

The portion of North Bengal which falls in the Darjeeling district consists of coarse flood plain deposits in the foot-hills culminating in the north by high level terrace-gravels, which are again succeeded in the north by fresh water Tertiary sands, conglomerates and clays comprising the Siwalik System. The Siwaliks on the north area faulted against Permo-Carboniferous Gondwana outcrops which contain sandstones, shales and thin coal seams.

The Gondwanas rest against a vast series of ancient metamorphic rocks, known as Dalings, which consist of slates, quartzites and phyl ites. The Dalings grade imperceptibly upwards in the stratigraphic succession to still more metamorphosed rocks consisting of mica-schists and gneisses, the latter often containing sills of basic rocks and are also permeated with granitic material.

The fresh water Siwaliks are found almost continuously from close to the Mechi river in the west to the Jaldhaka in the east but for short gaps such as on the left bank of the Balasan, west of Chunabhati, and in the area between the Chel and the Neora rivers.

The Gondwanas are absent between the valleys of Balasan and Mechi, and also between the valleys of Chel and Neora. A new type of rock, the Buxas, which are younger than the Dalings but older than the Gondwanas, consist of dolomites and slates, and crop out only half way between the valleys of Neora and Jaldhaka, the length of the outcrops being of the order of about 8 miles. The Buxas extend to the east along the strike into the territory of Bhutan.

Being a forbidden country, little is known of the geology of Bhutan, except that of the foot-hills region. The rock types are the same as are found in the foothills of the Darjeeling district, namely, the alluvium of the plains bounded on the north by the fresh water Tertiary (Siwalik) sandstones and clays. These are followed on the north by a strip of dolomitic limestones of doubtful age (Buxa) and the Gondwanas which again are bounded on the north by Daling slates and phyllites. The Dalings presumably grade on the north into metamorphic rocks such as mica-schists and gneisses.

The valley of the Tista from its confluence with the Rangit to Dikchu consists of Daling slates and phyllites. The grade of metamorphism noticed in these rock types increases progressively towards east so that at elevations of over 5,000 ft. the rocks are mostly mica-schists and gneisses.

In the valley of the Rangit from Nayabazar to Khandosanghphu, the rocks range from the dolomitic limestones to slates (Buxa ?) ; these are overlain by pebble beds and bouldery slates containing Upper Carboniferous marine fossils at Khemgaon and Wak. These are overlain by Gondwana sandstones with slates and carbonaceous seams containing plant fossils. As a result of overfolding, the Gondwanas appear to rest below Daling phyllites on the north. The low grade dalings grade imperceptibly into high grade gneisses and schists. The rocks of Western Sikkim continue into Eastern Sikkim (east of the Tista) through a roughly semi-circular swing.

SOILS OF DARJEELING AND SIKKIM

The soils in the area may be classified according to the composition of the rocks from which they have been derived.

1. *Soils of Terai region*

In Terai region, the soil is usually the older alluvium which supports Reserved Forests of the State in the north and varied agricultural crops in the south. The texture of the soil is coarse and in composition sandy.

2. *Soils of the Siwaliks and of the Gondwanas*

The soils derived from above form the steep slopes and are deficient in plant nutrients and consequently only suitable for forests of timber.

3. *Soils derived from the Daling slates and phyllites*

Both in Darjeeling and in Sikkim, these soils usually support monocultural cultivation on the slopes and multi-cultural in the flat plains and terraces near the valleys. Jhuming or shifting cultivation, deforestation, overgrazing, and cultivation on steep slopes have caused soil erosion and landslides, besides making the soil poorer in plant nutrients.

Agricultural Aspect of Soil

Besides geology, several other factors such as rainfall, altitude and aspect of the hill slope effect the soil from the point of view of agriculture.

No crops except potatoes can be grown above an altitude of 9,000 ft. ; the limit of cultivation for potato in Northern Sikkim in the Lachen and Dachung valleys is about 10,500 ft. Millets and maize grow on unterraced slopes. Rice grows usually below 4,000 ft. and invariably the fields are terraced.

Out of a total of 1192 sq. miles for the Darjeeling district, 259 sq. miles are under tea leases, 437 under Reserved Forests and 33 under Cinchona, leaving a residue of 463 square miles for unreserved forests and cultivation.

In the Darjeeling district, the agriculturists recognise three types of soil in the hills, white, red and black. Of these, the black soil is the richest, the white the poorest, the red soil occupies and intermediate position, requiring heavy manure. The greater portion of the hilly areas lies on the Darjeeling gneiss which most commonly gives a stiff reddish loam but may also produce almost pure sand or a stiff red clay. Generally speaking soils throughout the district are deficient in lime.

GEOLOGICAL ASPECTS OF FLOODS

Floods are primarily due to abnormal rainfall in any season or heavy rainfall for several days together in the catchment area. When the ground becomes fully saturated with water, as is normally expected in any area having considerable rainfall, the remainder being unable to penetrate into the soil passes off as run-off. The persistence of cloudy days in between raising periods retards the evaporation of moisture from the water-soaked soil and indirectly adds to the run-off.

During the pre-monsoon months local storms occur in the hills from the monsoon current emanating from the Bay of Bengal. From the middle of June onwards, depressions in the plains cause precipitation of the moisture before the rain-bearing clouds strike against the hills. If for some reasons such depressions are absent in the plains, a major part of the moisture is very likely to be precipitated in the Himalayan catchment.

Landslides

The slopes of the mountains become unstable when the amount of rain exceeds a certain optimum limit. The removal of soil adjoining a slope can take place suddenly by landslides or slowly by soil-creep which induces a slow and gradual downward movement of the soil. Soilcreep at some later stage may develop into a landslide. Another and apparently less detectable way of removal of land is by soil erosion. The factors controlling landslides are complicated ; their chances are augmented by lack of drainage which increases the pore pressure and therefore reduces the co-efficient of internal friction. Increment of the angle of slope also decreases stability, thus a large volume of water often erodes the banks of the streams and these increases slope angle of the banks, thereby causing unstability.

Mudflow, a variety of landslide, occurs abruptly almost without any warning. Such mudflows at Ligship and Bhondikhola have caused loss of lives in Sikkim.

The material of landslides is carried down by rivers as sediments and is deposited year after year in the valleys of the piedmont plains. Thus the beds of the rivers continually rise in the plains thereby reducing the capacity of the streams and rivers to store water.

Natural dams

Another important cause of floods is the formation of natural dams which are caused by the blocking of the river course by debris from landslides. As a result of which water is stored on the upstream side forming natural lakes of reservoir which flow out quickly causing flood where the dam fails due to pressure. The existence of several such ancient natural dams has been located in Sikkim. One of them, through which water is now finding an exit, occured in 1948 in the valley of Lachen by the Pemikhangchen rockslide.

A glacial lake can sometimes be formed by the blocking of its valley by morainal matter, mudflows and avalanches. Such dams may be breached either by excessive melting of snow in the catchment above the lake or by spilling of the lake by avalanches. The Sebu Chho lake-burst at the head of Lachung river caused the maximum rise in the level of the Tista in 1950. This had proved fatal to six people at Phunekongma in Sikkim.

Other Causes of Floods

Floods can be accelerated on account of lack of suitable soil cover which increases the run-off unduly. Soil is also lost on account of lack of well-managed forests, shifting cultivation, forest fires, over-grazing and unscientific land use, including wanton deforestation. Besides monsoon conditions, which aggravate landslides, earthquakes in the past have also been responsible for setting up of enormous landslides in the Himalayan catchment of Sikkim, Bhutan and Darjeeling. A somewhat slower change in the topography is possible by the secular rise and fall of the ground below the Himalayas probably extending over a long period of time. Some geologists are of the opinion that the continuous eastward drift of the Tista is perhaps associated with such slow secular movement. About 200 years ago, the Tista used to drain into the Ganga instead of into the Brahmaputra as at present.

REMEDY FOR FLOODS

Generally speaking, two types of remedial measures can be suggested for the control of flood : (1) by engineering structure and (2) by proper management of the watershed.

Control of Floods by Engineering Structure

A high dam and subsidiary check dams can be

constructed to intercept the flood water before it enters into the plains.

Dam-sites in the Tista Valley

During the reconnaissance of the Tista basin in 1954, the site of a high dam (27°01′40″ : 88°26′6″ : 78 A/8) originally investigated by Dr. J. B. Auden of this Department, was inspected at 29½ milestone on the Siliguri-Gangtok motor road near Giellekhola. The dam was to be found on Diorite gneiss and was proposed to be 500 ft. high of the curved gravity type. The Diorite gneiss is interbedded with the Daling phyllites. During 1947, some exploratory tunnels were driven in the abutments, but the project was later shelved possibly on account of the partition of the country.

The sites of several check dams are also suggested as part of the measures to control floods:

(1) *Mankha Dam*
The dam site is situated near the Mankha suspension bridge. The alignment of the dam will be right angles to the course of the river Tista which here flows towards W.N.W. The width of the river is about 120 ft. The rocks here are quartzites dipping 40° to N 45°E.

(2) *Kambul Dam*
A constricted gorge exists on the Tista near Kambul village. The rock is phyllite.

(3) *Selem Dam*
This site, (not examined) is situated about 300 yards upstream of the confluence of the Tista with the Talung river.

(4) *Tung Dam*
This is located about 300 yards upstream of the Tung suspension bridge. The rocks here are banded biotite-gneisses, the foliation of which is inclined at 70° to the N.E. The height of the projected dam will be about 200 ft.

(5) *Pagong Dam*
A dam of the height of about 100 ft. can be built on quartzitic rocks about 200 yards upstream of the Raye Chhu-Tista confluence.

(6) *Chungthang Dam*
A 200 ft. high dam is possible about 300 yards south of the Chungthan suspension bridge. This will, however, submerge the village.

(7) *Palo Dam*
The construction of a 150 ft. high dam is feasible on the Lachung river near Palo.

Dam-sites in the Rangit Valley

Since the construction of a high dam near Giellekhola will submerge the Rangit valley up to Naya Bazar, the construction of a separate high dam on the Rangit will be redundant. The sites of some of the check dams on the Rangit are suggested below :—

(*a*) *Dam near Kalet Chhu*
A check dam is possible just downstreams of the Kalet Chhu-Rangit confluence. The dam would rest on quartzites which dip in the upstream direction. The height of the dam would be about 150 ft.

(*b*) *Tassiding Dam*
About a mile and a half upstream of the Tassiding suspension bridge, a 150 ft. high dam is possible to be built on quartzitic rocks.

(*c*) *Rathong Chhu*
A dam about 200 ft. high is possible to be built about 150 yards downstream of the Rimbi-Rathong Chhu confluence on kyanite-schists. The height of the projected dam would be about 200 ft.

Some dam-sites in the Kalimpong Sub-division

Lish basin
The discharge in the Lish river varies from 9 to as much as 9,100 cusecs. The annual rate of siltation at the highway bridge is 1.5 ft. per year and the average annual rainfall is 192 inches.

Two sites for check dams have been suggested in the Lish valley—one, about 140 ft. high at the confluence of the Lish and Turung Khola, while the other is at about 300 yards downstream of the Nobgong Khola-Lish river confluence. In both places the rock is quartzite.

Gish river
The discharge varies from 3 to 22,200 cusecs. The longitudinal gradient is 115 ft. per mile and the total length of this river is about 16 miles. The annual rainfall in the catchment is of the order of 212 inches.

The best dam site exists on the Siwalik sandstones about a mile downstream of the Reserved Forest-Khasmahal boundary. Another alternative site, also on Siwalik sandstones, is at the intersection of 12.3 horizontal grid with the Gish river.

Chel river
The maximum discharge is about 6,500 cusecs. The longitudinal slope of the valley averages 275 ft. per mile, while the annual rainfall is about 240 inches.

The siltation here is much more heavy than in the other rivers of the Kalimpong area. One dam site has been located on quartzites in the bed of Kali Khola at about 271′ latitude.

Neora river
The discharge varies between 85 and 8,500 cusecs. The total length of the river is about 36 miles, and the annual rainfall 251 inches. Since the catchment is devoid of major landslides, no site for a dam has been suggested.

Relli river
The total length of the river is about 19 miles, the discharge varies between 20 and 20,000 cusecs. The longitudinal slope is 60 ft. per mile, and the average rainfall is 99 inches. Its catchment area (64 sq. miles) is more densely populated (19,500) than other river basins of Kalimpong.

A 100 ft. high dam of quartzitic rocks is possible at the site of the ropeway station. The width of the narrow gorge here is 360ft.

General observations

The sites of all the check dams have been selected by the writer at the time of the reconnaissance survey. Before it is finally decided to take up construction

work, they will have to be throughly investigated and explored. By collecting hydrological data the life of the dams can be ascertained.

There should not be any dearth of aggregate for construction, but cement will have to be imported from Assam.

In the course of geological mapping in Western Sikkim, the writer discovered a limestone band (38ft. thick) in Naya Bazar which yielded on analysis :

Insolubles	*Fe* 203	*CaO*	*MgO*	*Loss on ignition*	*Total*
22.36	A1203 1.70	40.60	0.98	33.38	99.02

If suitable reserves are proved, construction of cement facto y may be taken up, which will solve, the problem of the supply of cement for the construction of dams in the Rangit valley.

Control of flood by watershed management

The construction of dams will no doubt have an immediate beneficial effect in retaining both the silt and the water on the upstream sides. But these methods alone will never be able to stop the principal causes of floods, viz. siltation and excessive run-off. The foremost remedial measure will, therefore, be the treatment of landslides either by constructing suitable masonary retaining walls at the base of the affected slopes or by growing vegetation on the affected slope as well as in the overlying area. As long as landslides in the catchment area remain effective, whatever conservation measures are undertaken in the rest of the area, the results are bound to be ineffective.

Thus landslides are to be protected both by engineering structures as well as by afforestation under expert geological advice. Recently, a proposal is afoot to survey the areas affected by landslides in Sikkim by aerial photographs on a large scale.

The details of the areas affected by landslides in the valleys of the Rangit and the Tista are given as follows.

TABLE 1

Details of Landslide Affected Areas in Sikkim

Valley of the Rangit	*Co-ordinates*		*Area in sq. miles.*
Bhondi khola	27°7′	88°20′	1
Chongrang Khola	27°20′	87°16′	2
Narkhola	27°25′	88°20′	1
Brang group	27°23′	88°20′	10
Relli Chhu	27°23′	88°19′	3
Karchhi group	27°23′	88°19′	5
Kalet Chhu	—	—	—
Rinchinpong group	27°15′	88°15′	8
Rabong khola group	27°18′	88°20′	3

Total area affected by heavy landslides—33 sq. miles

Valley of the Tista	*Co-ordinates*		*Area in sq. miles.*
Rhenock group	27°10′	88°38′	4
Kasur	27°9′	88°31′	2
Temi	27°14′	88°26′	4
Brom	27°18′	88°26′	1
Ligni	27°23′	88°22′	4
Between Dikchu and	27°24′	88°31′	
Gyathang	27°29′	88°31′	10 (Zongu block)
Rangrang Khola	27°28′	88°33′	10 (near the source)
Fim chhu-Lachen confluence	6′	88°36′	8
Between Khedum and	27°37′	88°42′	
Lachung.	27°42′	88°45′	3

Total area affected by heavy landslides—46 sq. miles.

To cover a slightly larger area than is actually covered by the landslides, aerial photography with 60% overlap has been suggested for about 50 square miles in the Rangit, and 50 square miles in the valley of the Tista, preferably to the scale of four inches to one mile.

Even after something tangible has been done to check landslides, afforestation of such areas, as are devoid of suitable forest covers, should immediately be undertaken. It is heartening to note that the Forest Department of Sikkim, under the able guidance of its Conservator, Shri Arjan Sing, has made rapid strides in this direction. Before any scheme for afforestation in Sikkim is undertaken it will be prudent to demarcate areas under, and susceptible to, landslides under the guidance of a geologist. Grazing now indiscriminately practised both in Sikkim and Darjeeling will have to be strictly controlled and separate grazing areas should be earmarked.

As the practice of shifting cultivation is responsible for loss of soil, this should forthwith be stopped by legislation. Cultivation, if scientifically done by improved manure, strip cropping and by rotation of crops, will also add to soil conservation. What is now immediately needed is stoppage of cultivation of any sort by legislation on slopes exceeding 20 degrees (from the horizontal). Terracing should be encouraged by the State, if necessary with financial subsidies.

It should, however, be clearly understood that with the most effective and scientific land management no country can make any headway unless the schemes receive the full co-operation of the people themselves. Public recognition of land management problems should entail education in this aspect from the highest authorities downwards. Such a curriculum has to start from the primary schools by audio-visual appliances followed by demonstration and lectures.

It may be necessary to recruit a large number of villager, who have to be uprooted from their homes, and employ them for the treatment of landslides, while others can be induced to settle in the outlandish parts of the river basins.

CONCLUSIONS

If quick results are to be obtained from a scheme of soil conservation, both the construction of engineering structures and watershed management will have to begin together. The brown naked hills that one sees from the air beyond North Bengal will once again be green. Soil badly wrinkled and gullied will again be as it was a few centuries ago. The run-off will be controlled, the frequency of floods minimised, and the chronic scarcity of water during summer will be at an end. With less silt to flow into the rivers, the schemes will prolong the lives of the dams and reservoirs and ensure a constant flow of water for cultivation in North Bengal and East Pakistan. More forests will increase games and birds for sportsmen, besides yielding valuable timber. The scenic beauty will considerably enhance and invite trekkers and mountaineers.

Continued from page 29

Necessity of Centralised Water Control Planning Organisation in West Bengal

The pressure on land is already too high and practically all the available areas in the State have been put under cultivation.

To meet the growing demand of the agricultural produce, the only course left open for the State is not only to utilise her available water resources but to use the optimum quantity of water to enable a much larger yield of crops from the agricultural lands. It is therefore essential that the requirement of water for each variety of crop is determined as correctly as possible and steps are taken to ensure minimum use of water for getting the maximum yield of agricultural produce from the available lands in the State. No such planned attack in this direction has so far been envisaged. It is high time that the Water Control Organisation is set up and charged with the responsibility of increasing the yield of all agricultural produce to a figure already attained by other countries of the world.

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Soil Erosion and Silt Problems: Role of Forestry in Soil Conservation

and tribal welfare issues elsewhere. The complacant watching of the gradual deterioration of soil cover in Frontier or Tribal territory, especially where the land is hilly or undulating is a most indefensible position. Either government should adopt very stringent measures, or the people should be soaked and saturated with the principles and ideals of soil conservation so that they would accept voluntary restrictions or give full co-operation to Government's efforts.

Third, there should be a thorough investigation into the agricultural use of land in the mountains like the Himalayas as well as in small hill-systems as of the Santhal Parganas and rolling country as of the laterite zones of Midnapore, Bankura and Birbhum districts. It is well to realise that flat lands are the best suited for agriculture. No land with slope should be permitted to go under agriculture, unless careful measures are taken to see that no soil erosion occurs. Unbunded or unterraced cultivation of land must be totally stopped. One of the most ruinous kinds of cultivation is that which obtains on the vast rolling wastes of Midnapore, Bankura etc., where a once-in-four-year, unbunded dry cultivation is practiced, leaving the soil exposed to be dried in the sun and blown away by wind or washed down by the rains. There is no reason why part at least of these huge wastes (now eroding into the rivers and increasing their silt load) should not be put under pasture, which must, of course, be real fenced-in pasture, managed on the correct principles of rotational grazing. If however such lands can be put to no other use, Forestry would obviously be the best way of utilising them.

Fourth, through international co-operation we must have the Himalayan watersheds of Nepal and Bhutan put back under forest cover. This would be the most gigantic task of all. I cannot see how in the absence of this mighty effort we can ever hope to save the rich plains of Aryavarta, whose character, at the present rate, is likely to be so completely changed that we may in the course of the next 100 or even 50 years have to abandon very large blocks as not only unculturable but even unsafe for human habitation. The result will be a great reduction of our agricultural potential, and excessive crowding of people on the few strips of culturable land lying between the flood-ravaged regions of successive rivers. A century hence we must still sit up and work out the statistical possibility of maintaining the optimum number of human beings on our very seriously shrunken agricultural domain.

This may appear to be too gloomy a presage, but try how I would to look for consolation I do not find a ray of hope unless our planning takes into account the four factors which I have enumerated above.

Meanwhile, that is, until necessity of these imperative measures is realised in their enormous importance, it is the duty of the Forest Departments all over India to improve the water-retentive and soil-protective qualities of existing forests by increasing their density of stocking, by denying or withdrawing ruinous concessions to the public (whether tribal or civilised), by altogether precluding fire especially from the dry forests, and by afforesting the blanks in order to obtain continuity of beneficial influence.

The events of the next half century will determine our fate. If we choose the steep and narrow path of self-denial, self-examination and self-discipline we may hope for future prosperity. Otherwise we shall be merrily dancing our way down to dusty death.

Soil Erosion and Silt Problems : Role of Forestry in Soil Conservation

By V. S. RAO

IN spite of the many articles that have been written and the seminars that have been held on the subject of soil conservation I wonder if there has been adequate appraisal in our country of the disastrous results of soil erosion and general recognition that it is our public enemy no. 1. I do not think it has also been realised by thoughtful men that unless we can halt this process of soil erosion the ambitious Five-Year plans cease to have much meaning. Had we realised this we should have declared a state of national emergency and put the matter of soil conservation on a war footing instead of trying to tinker with it in the usual leisurely, highly judicial, tolerantly political, and totally inconsequential manner.

It is of the utmost importance that we take note of this fundamental fact : that soil is the source of all life on the continents, the basis of all civilised existence. It is the green plants that grow on soil and the animals that feed on those plants that are the sources of nourishment to man. Without such nourishment human existence was not possible. And the nation that has built factories, sky-scrapers and such wondrous edifices of civilisation but has managed to lose its soil is like the man that has acquired all the wealth of the world but lost his soul. Unless we can keep the soil intact and in good heart the rest of our activities will have little meaning. I find here a strange relationship between soil and soul. It is just a matter of U & I.

I cannot find in literature an apter illustration of the dire consequences of soil erosion than the monumental picture painted by Shelley (of all people) in his sonnet on Ozymandias :

> I met a traveller from an antique land,
> Who said : Two vast and trunkless legs of stone,
> Stand in the desert.....Near them, on the sand,
> Half sunk, a shattered visage lies, whose frown,
> And wrinkled lip, and sneer of cold command,
> Tell that its sculptor well those passions read,
> Which yet survive, stamped on these lifeless things,
> The hand that mocked them, and the heart that fed :
> And on the pedestal these words appear :
> 'My name is Ozymandias, King of Kings :
> Look on my works, ye Mighty, and despair'!
> Nothing beside remains. Round the decay
> Of that colossal wreck, boundless and bare,
> The lone and level sands stretch far away.

Many empires and civilisations have gone to dust since Ozymandias, but we persist in being no wiser today than we had been thousands of years ago.

If we look at the present map of India it is difficult to point out the really fertile regions. Large tracts of Rajasthan, Madhya Bharat and the Deccan plateau must obviously be classed as infertile. The coastal plain between the Eastern Ghats and the sea is not very much to speak of as an agricultural tract. Erosion of the deforested and bare outer hills and the dry climatic conditions induced thereby seriously impair the agricultural status of the land in this region.

Our main granaries lie alongside and towards the mouths of big rivers like the Ganga, Jumna, Tapti, Narmada, Godavari, Krishna, Cauveri etc. Rightly has it been said that man is a parasite on alluvium. This is particularly true of tropical and eastern countries. Where annual moderate flooding enriches the cultivated land, there is no trouble. We get all the manure we want from the rich silt. Where this does not happen, we appear to be helpless. The gradual deterioration of crop lands of Nadia District is said to be due to the fact that river silt no longer reaches the higher lands.

But the most tragic part of it is that these fertile lands alongside the rivers are now subject to floods of such magnitude that far from improving the soil, thousands of acres of crops are spoiled by prolonged inundation; and when the water recedes it is more and more common to find deposits of sand in place of silt, so that it would take years before the soil would again be fertile enough for crop-bearing.

This has happened in Assam and this is being experienced alongside the Tista and the Torsa (and alongside many other smaller rivers in between) in West Bengal. Bihar appears to have become a permanent competitor with Bengal and Assam. And Eastern U. P. does not apparently want to be left behind. It is a very peculiar thing that on the one side we are taking a lot of pride in our magnificent River Valley Projects which are designed to vastly increase our agricultural potential, we do not, however, seem to be taking into account the enormous losses of crop lands on the other side due to flood action, and striking the resultant position.

Two thoughts appear to be consoling the public including the thinking section. One: that these floods are a peculiar feature of a particular year of heavy rainfall; such things are bound to happen and we have to face them and do the best we can; we need not make any drastic changes in our economic structure or ways of living. Two the country has managed to get on with occasional floods, droughts, famines etc. for thousands of years—and surely it can go on for many more thousands of years in spite of the gloomy forebodings of a few cranky alarmists!

As regards contention no. 1, I should like to point out that never in the past history of our country have floods been a matter of annual occurrence. It is only in recent years—more especially after World War II—that matters have taken this strange turn. As for the seemingly sound and satisfying argument no.2, all that I can say is that if the Americans had taken the same attitude in regard to their soil erosion and flood problems during the last quarter of a century the course of history would have been totally different, as they would have ceased to be a world power by now.

What is imperatively necessary to realise is the great difference in speed (and volume or extent) between the intitial stages of the progression of a damage and that noticeable after it arrives at a critical point. For example if you start with number 2, square it and keep on squaring every successive number so obtained, you will very soon reach an astronomical figure. Two, four, sixteen, & 256 are fairly reasonable figures. The next one is 65,536, and the next is more than 42 crores. The figure that follows is certainly astronomical.

That is exactly what happens with the case of soil erosion and flood incidence. Upto a critical point the damage from deforestation appears to a reasonably moderate affair—nothing to worry about and lose one's sleep over. Beyond that crisis all the inmates of hell are let loose. I always considered a forest-covered hill slope as a Pandora's box whose lid is closed. You open the lid (that is, remove the forest cover) and lo! the imphs of havoc are released and go flying furiously about and won't be coaxed back.

To any one that has watched the hacking of woods in our mountain terrain (like the Himalayas) the scars that have been developing year after year on the denuded slopes would have been quite an unmistakable sight. To me they always figured as the literal "Writing on the Wall"—compared to which the writing which Belshahzar saw in the midst of his great carousing was but a shadow and a dream.

If we knew the language of this writing we should not have taken it so easy for so long. We should not have talked of growing more food at the expense of forests, especially on sloping ground and certainly not in the hills. We should not have made the forest a pawn in any political game and tried to purchase the goodwill of a short-sighted people by the sacrifice of the only buffer between us and sure calamity. Cut that barrier or *bund* and the mischievous waters flow with disastrous turbulence, as indeed they are now doing. We talk glibly of Kosi being Bihar's River of Sorrow, but we haven't yet been bold and honest enough to admit that Man is the Disease Organism of River Catchments.

What is the status of forests in our Himalayan mountains, to take only one instance? During the settled times we had for the last nearly two centuries great inroads have been made into the vast Himalayan forests from Kashmir to Bhutan. Not only much destruction has been caused to the forests of Nepal, Sikkim and Bhutan but even in our own domain we have kept the Forest Department out of large wooded areas which have since succumbed to grazing, fire and the axe. And now we expect the Himalayan rivers to flow in the same beneficent manner as in the days of the Mahabharata. This is, to say the least, rather unreasonable.

The great forests of the Plains and those of Dandaka (or Peninsular India) have been destroyed with the same thoroughness and spirit of unremittant plunder and war. We have watched with complacence the annual burning of the forests which still survive—burning that reduces their effectiveness as soil and water conservers; burning that renders them hollow, as it were, while still standing. Assam forests are riddled with shifting cultivation and the outer Eastern Ghats present an awful sight of bareness and barrenness.

In other parts, mining and quarrying, whether it is for gravel or dust coal or soapstone (for adulteration with *atta*;) or some such material of small and transient value are given preference over a perpetually renewable asset which in addition to meeting the needs of people for timber and fuel, renders gratis service in the cause of water retention, soil protection and climatic amelioration. This is certainly not the work of thoughtfull, civilized human beings. It is more like that of an army of vandals.

The most fundamental factor in forest destruction is the unchecked multiplication of the human population. This is a factor which in India, did not exist before the advent of the British and the establishment of peaceful conditions. When wars, famines, epidemics and similar calamities no longer ravage and decimate the population and serve to keep it within reasonable limits, the voluntary restriction of increase in numbers is an absolute desideratum for achieving a generalised prosperity and improved standard of living. It is obvious that the earth's resources can only meet the demands of a particular numerical strength of human population. Any increase of population beyond the critical point is bound to lead to a lowering of standards and to dangerous attempts at living on the capital instead of the interest. We have come to a stage when we have not only swallowed all the interest but have made very large inroads into our capital. To halt this process and restore sanity and orderliness we have to take charge of a few things.

First, we have to really and seriously set about limiting our numbers. We just cannot afford to multiply indefinitely. Unchecked increase of population is one of the direct causes of forest destruction and of the disastrous upsetting of the balance of nature.

Second, we must give up our misplaced sympathy with those who use forest produce to the destruction of the forest itself. Such misuse is obviously a case of killing the goose that lays the golden egg. These matters involve political questions near our frontiers,

[*Continued on page* 40]

Soil Erosion and Silt Problems: Role of Forestry and Soil Conservation

With special reference to Darjeeling and Sikkim hills

By A. C. GUPTA

Limitations of the human mind and memory do not as a rule permit of a correlation between cause and effect when these are separated by a considerable length of time, and this shortcoming in the average mortal is to a great measure responsible for his improvident acts resulting at first in the erosion of soil and later in landslips and floods.

Eastern Himalayas in retrospect

In the outer ranges of the Eastern Himalayas where many rivers of north-eastern India originate the rainfall is heavy and the rocks are mostly semi-crushed. The annual rainfall in the North Bengal hills vary between 80″ and 266″. Upto the middle of the 19th century when the population on these hills was very thin the balance of nature was well held, but thereafter with the gradual establishment of an ordered govt. and security, and with the increase of prosperity brought in by people from the plains, the population increased by leaps and bounds with the consequent increase of pressure on land required for the cultivation of food and other crops. A scramble resulted and in their anxiety to grab as much land as possible and as fast as possible quite a large number of people and particularly those with some local influence took possession of extensive areas including areas under forest cover. To offset such moves constitution of State forests started in the Darjeeling district—then called British Sikkim—in the year 1866, but it was not started in Sikkim uutil 1909 by which time a very great deal of mischief had been wrought. In Bhutan the matter of reservation of certain state forests was first taken up as late as 1955 when extensive disforestation had already taken place on the southern border of the country abutting on India.

Early History of Darjeeling

A peep into the early history would be helpful. Darjeeling as we know it, came into being in 1835, and to be known as British Sikkim for many years thereafter. Both British Sikkim and Sikkim proper were then well wooded, and problems arising from soil erosion were few. Tea gardens which brought early prosperity to the Darjeeling hills started being opened soon after at the expense of the forests and drew a large influx of population from the adjoining Nepal. The virgin forest land being very fertile, a part of such population took to cultivation, and no control on land settlement having existed at the time they took possession of any unoccupied forest lands they liked and practised shifting cultivation thereon. With the passage of years areas were laid gradually bare of their soil cover and the

Fig. 1. Semi-crushed phyllite in a profile in the upper catchment of the Lish where may landslips occur.

Fig. 2. Private forest under clear-felling for cultivation in Sikkim. The beginning of a slip is seen in the background.

Fig. 3. The 6000 ft. altitude line (approx) marks the boundary between forest and cultivation.

Fig. 4. Khas Mahal forest in the process of destruction.

Fig. 5. Steep hillside in the background has just been cleared for cultivation, while the area in the foreground is resting.

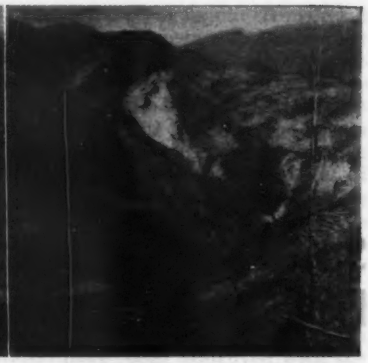


Fig. 6. The ultimate result of shifting cultivation on steep slopes.

holdings had to be extended; and this unfortunately continued for very many years before notice was taken and regulations were made and enforced. Tea gardens and cultivation sprang up haphazard all over the hillsides, but mainly below 6000 ft. altitude where living conditions were comparatively easier. Things had come to such a pass by 1860 that the authorities were compelled to take a very serious notice of the situation, and the most important measures they instituted towards arresting further denudation of the hillsides included the inauguration of a Forest Department in 1864, and the gradual reservation of forest areas against alienation from the year 1866. The early development of the Darjeeling hills not having followed a plan drawn up in advance, the status quo had to be accepted when reservation started in 1866, and the consequent position to-day is that practically no forests exist between the 6000 ft. altitude line and the foothills, which in the early days were dreaded for the disease, the various blood-sucking flies and the dangerous wild animals then harboured, and it is mostly in this denuded part that the highest soil erosion takes place, and the large majority of landslips occur.

Case of Sikkim

Things in Sikkim stood somewhat differently. It has no industries even to-day and its prosperity, which may correctly be called reflected prosperity, followed in the wake of that of Darjeeling. The market of Darjeeling gave a fillip to the breeding of horses, cows, sheep and goats, the formation of orange and apple orchards and the cultivation of cardamon, cereals and vegetables. The Nepalese were quick to see the possibilities, and they migrated in large numbers from Nepal. It seems that an appreciable increase of the population of Sikkim did not begin until the beginning of the present century, and exactly what had happened earlier in Darjeeling happened in Sikkim about 60 years later. A Nepalese cultivator, about 80 years old, whom the author met in a remote part of Sikkim told the author that he with some of his friends had migrated from Nepal some 50 years ago when a great deal more of forests existed in all parts and when therewas no scarcity of water as now was. The position in Sikkim to-day is distressing. The residual forests besides the small scattered monastry forests are generally restricted either to the more inaccessible parts above 6000 ft. altitude in the south and middle, or the areas in the distant north, very difficult of access. Administration is very lax, and what could be saved even now is fast disappearing. Roads and rest houses are scarce in Sikkim, but it is only where roads and rest houses occur that some good terraced fields can be seen. Elsewhere, it is a different story, and terraced fields are more of an exception than a rule.

Fig. 7. Bulkwheat has been sown on this skeletal soil at the foot of a landslip.

Fig. 8. Hills heavily clad with a virgin forest. In spite of the heavy rainfall no slips are visible.

Fig. 9. The former Rongo forest block which has been named Gouribas by presumptive settlers who came in the guise of Cinchona Labour.

Fig. 10. Slip cycles have formed on what was thickly covered with forest less than 20 years ago.

Steep to very steep hillsides are under shifting cultivation, and this very objectionable practice has in many places caused either slip cycles to form in numbers or even slips to descend. Uncontrolled grazing on hillslopes is not compatible with the conservation of soil, and yet certain forest areas on very steep slopes have been set apart as pastures, but no rotational grazing is enforced.

Fresh detritus deposited at the foot of a slip is often allowed no time for consolidation and is brought under cultivation at once. It may be said that large scale deforestation and mismanagement of the soil started in Sikkim only 50 years ago, and that these proceeded sufficiently far to make their cumulative effect appreciably felt in the Bengal plains from 1948 onward. It may be further said with certainty that if the various malpractices that either bring about or encourage soil erosion are permitted to continue unchecked the floods in the future years will gain in tempo and will devastate the countryside in the lower reaches to which a feeling of false security has been imparted by the recently put up marginal embankments.

Role of Darjeeling Rivers

To the floods and devastations that occured in the North Bengal plains during the past 8 years some of the rivers and streams that originate in the Darjeeling hills made a substantial contribution, and amazing as it may seem, several of these have their catchment in the Reserved Forest. If truth has to be told, the system of land management of the Darjeeling hills is very far from satisfactory, and unless some radical changes are effected in the administration no improvement is possible. The Nuxal Khola, a tributary of the notorious Jaldhaka river, and the Neora may be cited as two good illustrations. The Nuxal Khola has its catchment in the Rongo forest (Kalimpong subdivision) which has the highest rainfall in North Bengal, it having amounted to nearly 350″ in 1954. Yet of all areas this block of Reserved Forest was selected in 1938 for opening out and for conversion into a Cinchona plantation. Extensive clear-fellings were made in the very rich timber forest for reasons other than scientific or commercial, but the prevailing conditions having proved unfavourable for Cinchona, only a small proportion was restocked with the plant, the remainder of the clear-felled area being either left fallow, or brought under the cultivation of food crops. A large labour force was recruited and settled in the area regardless of the fact that the status of the plantation remained experimental. The position at the close of the year 1955 was that out of the 1500 acres clear-felled no more than 660 acres were under Cinchona, and the labour force together with their families numbered 3000, all settled on the soil. What was a thick forest not very long ago now has the appearance of a prosperous village with a large population. This very improvident act will spell disaster in the years to come, and severe will be the retribution of Nature.

Silps cycles have already appeared on certain hillsides left bars for several years. A part of the Rongo Block has since been placed under the management of the new organization set up for the cultivation of medicinal plants. The Neora river which drains a large area of the Kalimpong Reserved Forest carried down huge quantities of detritus during the 1954 flood and tore away the long steel bridge that stood for years on the Assam Access Road. The principal and immediate cause no doubt was an abnormally high atmospheric precipitation within a short space of time, but quite a big contributory cause was a chronic presence of a large number of illicit cattle "Bathans" in the Catchment forest, and the consequent browsing, and trampling of the soil by hundreds of animals from year to year. No serious attempts are unfortunately made to remedy the position. In one raid many years ago the author rounded up some 500 heads of cattle in this area.

The Lish is another small river originating in the Darjeeling hills which has caused for many years a great deal of worry particularly to the road engineers. Its catchment is very small, and it does not go beyond 5 miles of so from the foot of the hills, but the river carries down such a tremendous amount of detritus each year that its bed keeps on elevating at an alarming rate. The upper part of the catchment is very delicately built being composed principally of semi-crushed phyllite, and instead of being treated with the respect that was its due the area was subjected to the utmost

Fig. 11. The remains of the Neora bridge—a tangled mass of steel after the 1954 flood.

Fig. 12. A slip in the upper catchment of the Lish which has been suffered to develop for many years.

maltreatment under the Khas Mahal, and the inevitable occurred. Soil erosion has been heavy and some of the slips that formed increased in dimension from year to year and are still very active. After a great deal of arguments over many years during which time the slips went on expanding merrily, only a part of the catchment area was transferred to the Directorate of Forests a few years ago, but since this transfer which no doubt put a stop to the felling of trees, grazing and cultivation, nothing tangible has been done to deal with the menacing slips. The treatment of slips required very specialized knowledge in addition to experience, and unless these are available collosal wastes of money, labour and materials are bound to result.

The Case of Check Dams

It would be a pertinent question to ask if it would be technically correct to undertake the construction of check dams in the rivers and their tributaries that are subject to seasonal flooding. To the author's mind the answer is a yes if soil erosion on the hillsides has been brought under control, and the silt charge the waterways have to carry is reasonably small, but the answer is a no if soil erosion continues heavy. Check dams in effect step up the bed of the river and thereby reduce the velocity of the flow. If the water carries an undue amount of silt charge the bed will soon rise at first on the upstream side of the dam, and then on its down-stream side, and after a short while the dams will be buried. The net effect will be a general rise of the bed in the region of the dams, the disappearance of the step feature, and an increase in the degree of overall slope of the river bed. This would hardly be desirable. The next question one may reasonably ask is whether a survey and an investigation for the purpose of putting up check dams are likely to be productive of any good before soil erosion has been checked and brought within reasonable bounds. The author confidently feels that the answer to the question is a no. Forestry combined with a certain amount of forest engineering is the only known effective method of restoration of equilibrium where soil disturbances have been both intensive and extensive while the terracing of the fields is the only solution where damage has not proceeded too far and the slope is well below the critical angle. Both these operations, which involve survey, planning, finance and labour, are likely to take a considerable length of time, and particularly the former which may involve in addition the rehabilitation of the evicted tenants. By the time these operations are completed the characters of the water courses may have changed fundamentally, and the data collected many years ago may have lost their value.

Fig. 16. A network of underground rhizomes of A maling.

Forestry as an instrument

The pressure on land for cultivation being on the

Fig. 13. A view of the Ralli in the upper catchment of the Rungeet showing the high bed slope.

Fig. 14. The Brang group of slips in Sikkim where an entire hill has been affected.

Fig. 15. Arundinaria maling—a single stem (non clump forming) bamboo.

[*Continued on page* 65]

Reconnaissance Survey in the Upper Valley of the Teesta River

By V. S. RAO

THE northern catchment of the Teesta is comprised of the entire State of Sikkim which is roughly rectangular in shape (60 miles by 40 miles) the longer side of which is north-south, which is also the general direction of flow of the Teesta river. Starting from about the middle of the southern border of the State and going up the river one finds a fork at Chungthang, a village 10 miles to the east of the geographical centre of this State and 36 miles north by road from Gangtok. (Here is the last post office; further north the country is little developed or opened up). The western prong of the fork which is the bigger and longer is known as Lachen, the upstream journey along-side of which takes one to within 4 miles of the the Sikkim-Tibetan border, where there is an easterly bend; in this east-west part of its course the river is known as Chombo Chhu. About 15 miles beyond the bend is the origin of the Teesta (or Lachen or Chombo Chhu) from lake Khangchung Chho at an elevation of 18,000 ft., north-east of the Donkya La (pass). The eastern prong is the Lachung river which has its origin in the southern slopes of the Donkya Rhispur.

The Lachung drains a comparatively small portion of the catchment (about 60 square miles) but being a short river arising out of snow-clad mountains (above 17,000 ft.) it has a steep gradient of 1 in 16 during its 36 miles course to Chungthang (5,280 ft.). The Lachen which in its 50 miles course has a gradient of 1 in 20, drains an area about thrice the Lachung catchment. Its tributaries arise from the edges of the extensive masses of snow and glaciers in the north-west of Sikkim, notable among which are the vast Zemu glacier, and the great snow-covered ranges of the Lhonak region. The gradient of the Teesta between Chungthang (the confluence of the Lachen and the Lachung) and Singhik (about 12 miles south) is still fairly steep (1 in 30), while from Singhik to Singtam (1,400 ft.) a village about 4 miles from the southern border of the State, the average gradient is 1 in 120.

The bigger of the sub-drainage systems of the Teesta Catchment are mentioned below :—

(i) The Zemu Chhu and its tributaries drain the large north-western sector and carry the water into the Lachen from its right bank;

(ii) from the left bank of the Teesta enter the drainages of the Dikchu, the Rongnu and the Rangpo, all of which collect the waters of the south-eastern zone;

Donkya La (Pass) 18,030 ft. is the dividing line between the catchments of the Lachen and the Lachung which later meet at Chungthang (5,280 ft.) to form the Teesta.

Photo—G. N. Dutt

Cholamo Lake (16,500 ft.) looking N.N.W. from the northern slopes of the Dongkya La.

Photo—G. N. Dutt

Cholamo Lake with Sanglaphu (snow-clad) 20,420 ft. in the distance.

Photo—T. K. Mitra

Barren high level plateau near Cholamo; the snow peaks in the distance are in Tibet. These region are the play-grounds of unbriddled elemental forces.

Photo—T. K. Mitra

(iii) the Tulung Chhu drains the mid-west and enters the Teesta from its right bank: the drainage of a very much larger area in the south-west is gathered by the many-branched Rangit river system.

The Rangpo and the Rangit enter the Teesta from its left and right bank respectively at the southern border of the State.

From about 750′ at Melli (near the southern boundary of Sikkim)the land rises to very high altitudes (18,000 ft. to over 23,000 ft.) in the north-west, north and north-east; these high lands surround the central lower areas of the State in the shape of horse-shoe. The north-western portion is, however, the vastest. These elevated regions (especially above 16,000 ft.) are bleak and barren, with exposed rocks and crags, or permanently covered with snow and glaciers, and are totally inhospitable to life of any sort—man, beast, bird, insect or even vegetation. They are the play-ground of blizzards and snow storms and such furious unbriddled elemental forces.

Civilized life is therefore mostly confined to a region covered by a lop-sided parabola with the southern border of the State as the base and Chungthang as the crest, with a steep eastern arm and a more gently sloping western arm. It also creeps up the Lachen and Lachung Valleys, fading out at Thangu on one side and Yumthang on the other. Descending from the snows one comes across alpine grass-lands at altitudes of 16,000 ft. to 14,000 ft. Below this (and down to 13,000 ft.) there are dense masses of low shrubs (Cotoneaster etc.) and gnarled and stunted rhododendrons, the toughest and stubbornest warriors holding the fort of the plant kingdom against the severe fury of winds and cold temperatures. The next 3,000 ft. form the region of the conifers (silver fir, larch, and juniper) with an under-storey of rhododandron and wild roses.

Gordama Lake and glacier (17,800 ft.)

Photo—P. K. De

Another view of Gordama Lake

Photo—P. K. De

Looking N.E. towards Gordama Lake; picture shows the terminal moraine (M) of the Kanchanjhau glacier and the terminal moraine (T) of the Sanglaphu Glacier.

Photo—G. N. Dutt

Typical bleak high altitude country near Dongkong, with the 22,403 ft. snow-clad Chomiomo in the back-ground; much above limit of tree growth.

Photo—T. K. Mitra

In the less severe conditions obtaining in the 10,000 ft.-8,000 ft. zone other hardy conifers like the hemlock and spruce make their appearance accompanied by a broad-leaved retinue of high level birch (*bhujapatra*), poplar, maples and laurels. Below 8,000 ft. occur the more typical broad-leaved forests of the Eastern Himalayas, with oaks, chestnuts, laurels, maples, alder, birch (*Betula alnoides*) and a host of other kinds of plants which break up the rock, build up the soil, enrich it with humus and make conditions suitable for animals and for that flower of earthly life, *Homosapiens*, whose ungrateful attitude towards this beneficent plant kingdom and unwise exploitation of the rich soil built up under its regime have in recent years caused untold misery and the wide-spread disasters which led to the exploration of the frontiers of life by this expedition of scientists in September-October 1954.

The foregoing two paragraphs give the general pattern of plant life in this zone which may vary slightly from place to place, depending on the local conditions of aspect, slope, precipitation, etc. Forests, when undisturbed, reach down to the river banks and, by the protection afforded to the soil by their canopy against heavy rain and by the reinforcement effect of their interlaced root systems underground, hold the hill sides (rock and soil) in position and filter the run-off water that gets into the streams and rivers.

The high level regions (16,000 ft. and over) of bare rock and snow comprise quite two-fifths of the land surface of Sikkim. About 50% of the rest of the area is nominally under forest (Reserved and Khasmahal) but the cover is not uniformly dense owing to human interference, especially in the Khasmahal section. The rest of the area (barring steep and precipitous slopes of 70° or over) has at some time or other been under cultivation, there being many sites which have been abandoned due to impoverishment by continual cropping, surface erosion, gully erosion, soil slips or land slides.

Geology

The southern half of the Sikkim State constitutes a part of the Inner Himalayan region, while the northern half falls in the zone of the Central Himalayas; the two halves may be roughly indicated by an east-west line passing through Chungthang. Comparatively hard and resistant rocks, like schists and gneisses occur in

Decomposition of rocks near Momsemdong (15,100 ft.) effected by alternate freezing and thawing.

Photo—T. K. Mitra

Enormous deposits of scree occupy the northern slopes beyond Donkya La. The reconnaissance party toiling up the slope.

Photo—G. N. Dutt

northern Sikkim and the land surface is therefore not easily erodible. In the eastern section, especially east of Gangtok, the underlying rock is stable, being composed of banded schists and ortho and paragneisses. The western and southern regions are formed of softer phyllitic strata. It is in this last-mentioned region

Snow-capped Kanchenjhou (22,603 ft.) seen from mile 70.

Photo—P. K. De

that extensive cultivation takes place, leading to serious soil erosion.

The phyllitic strata, being of sedimentary origin, are liable to slip and slide by failure of the rocks along the bedding planes and along planes of unstable joints, when the geological formation dips at an angle greater than the slope of the hill. Dips of 25° and steeper form danger zones; soaking of the soil and movement of the water along the bedding planes causes the movement of rock and soil.

Glacial moraine deposits of great depth (upto 1,000′) occur in northern Sikkim and are especially charac-

Cauldron-shaped valley of a tributary of the Lachen, indicating glacial action.

Photo—T. K. Mitra

teristic of the Lachung Valley.

Rainfall

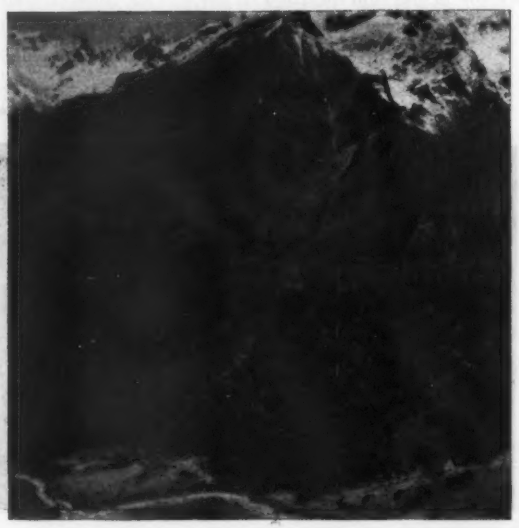
Unlike the western Himalayas, the eastern region (part of which is the subject of our survey) is characterised by heavy precipitations of up to 150″ annually in various localities. Lower down the Teesta Valley and in the hills south-east of Sikkim the total annual

The Himalayan Club hut (roofless) at Momsendong (15,100 ft.)

Photo—P. K. De

The upper limit of tree growth as seen from Thangu.

Photo—T. K. Mitra



A view of the Lako Khangse Glacier north-east of Yunthang Dak Bungalow. A mud-flow (M) recurred in the old channel ponding the Lachung temporarily. AM—ancient mud-flow.

Photo—G. N. Dutt

Steeply dipping (N.E. at 65°) quartizite (Q) at Chungthang suspension bridge lying below gneissose rocks. Amphibolite sills (A) vary upto 3 ft. in thickness. During the Fim Chhu dam burst in 1948, the water in the river touched the bridge.

Photo—G. N. Dutt

rainfall is as much as 250″ or even 300″ (e. g. the Murti Valley). But in Sikkim proper the annual precipitation is about 135″ in the vicinity of Gangtok; the extent of rainfall decreases as one goes up the Teesta Valley, being 100″ at Chungthang and 60″ (estimated) at Lachen and 30″ at Thangu. At Rangpo on the southern border it is 80″. These quantities are fairly heavy for a catchment of this nature. On the higher altitudes it is probably very much lower, but considerable snow fall takes place, the melting of which in summer provides streams with large quantities of water. Rainfall is of the monsoon type and is concentrated in the period June-September. Heavy and concentrated downpours are not an uncommon occurrence in this region.

Snow-falls occur in this catchment above elevations of 9,000 ft. only. The region of permanent snow is normally above 16,000 ft.

Temperature

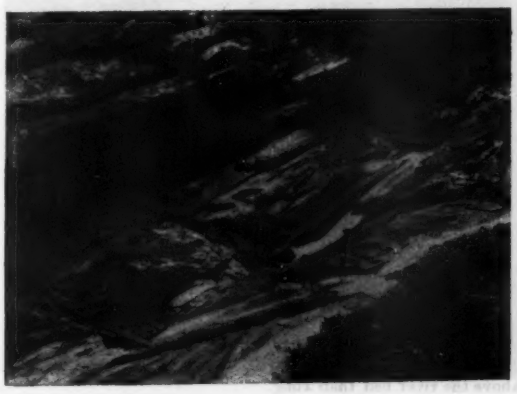
The valleys of lower Sikkim are hot and moist in summer. The climate of the snowy ranges and glacial region is of the arctic type. In the rest of the country, the climate is naturally of an intermediate type varying with altitude, latitude, aspect, etc. At the higher altitudes where biotic influences are absent, the alternate freezing and thawing of water accounts for a certain amount of rock-weathering, the resultant rock fragments being washed down by the sow-melt.

The Investigation

The above description of the country and the climate forms the basis for the study of the causes of the floods in the Teesta and of the remedial measures which can be adopted for reducing their frequency or intensity. In connection with the problem of flood control the following questions arise:

Gneissic rocks with fairly low joint dip (North 35°, at 15°) at the *nala* near milestone 25° ; the foliation dip is 55½° towards E N.E. (70°). There is a 200 ft. long slide caused by weak joint planes upstream of the *nala*

Photo—G. N. Dutt



The hill slope on the right bank of the lachung river, deforested and being used as grazing ground

Photo—P. K. De

(a) What are the causes of the floods of 1948, 1950, 1952 and 1954, apart from just heavy and concentrated precipitation?

(b) Are the floods due to progressive deterioration of conditions in the catchment which can be stopped or arrested? Do such conditions still exist and are they likely to give rise to disastrous floods in the future as well?

(c) Are these matters of the nature of unpreventable happenings of great magnitude beyond the power of human control and remedial measures? If not, what can human endeavour do to mitigate disaster and finally to eliminate it altogether?

It is with a view to finding answers to these questions that the reconnaissance survey of the upper valley was undertaken. The party ultimately consisted of four, viz.,—

(*i*) Shri G. N. Dutt of the Geological Survey of of India.
(*ii*) Shri P. K. De, Executive Engineer, Investigation Division No. II.
(*iii*) Shri T. K. Mitra, Divisional Forest Officer, Darjeeling Division.
(*iv*) Shri P. S. Subba of the Forest Service of the Sikkim State.

Reports were submitted by the first theree members of the expedition and the present write-up is an effort to condense the three reports and bring the materials together into a connected treatise.

Starting from Gangtok (5,680 ft.) the party got to the bank of the Dikchu (a tributary of the Teesta from the east) and followed its course westwards upto its junction with the Teesta (2,800 ft.) from where they proceeded north, northeast and north along the Teesta valley past Singhik* (44,600 ft.) and

A fine specimen of the Yak or Chamri, herds of which are grazed in high level pastures.

Photo—P. K. De

Yak grazing has to be "rationalised" in the interest of the local populace. This is too steep a hill side (Thangu 13,3000 ft.) for open grazing.

Photo—T. K. Mitra

Tong (4,400 ft.) to the junction of the Lachen and the Lachung at Chungthang (5,280 ft.). From here they followed the Lachen in a generally northerly direction past Menshithang (6,500 ft.), Lachen (6,960 ft) and Thangu (13,300 ft.) to Giogong (15,500 ft.) and thence in generally easterly direction to Chola Mo (17,100 ft.). The party then turned southwards and crossing the Donkya La at (18,100 ft.) followed the course of the Lachung almost from its source and travelled in a generally southward direction along the Lachung valley past Momesamdong (15,100 ft.), Yumthang (12,050 ft.), and Lachung (8,900 ft.) back to Chungthang. Thence the party retraced their steps along the Teesta Valley down to Dikchu from where they followed the Teesta south past Magka (1,850 ft.) to Singtam (1,400 ft.), where the journey ended. The actual marches from Gangtok to the north and down to Singtam were done from 27th September to the 18th October, 1954.

A lovely Silver Fir forest near Yungthang (12,050 ft.) symbol of peace and harmony.

Photo—T. K. Mitra

*This village is situated at a greater height above the river bed than Tong.

A Reserved Forest in the Lachen Valley, which provides full protection to the hill-sides.

Photo—T. K. Mitra

Badly managed Khasmahal Forests like this one at Samdong have poor protective value.

Photo—T. K. Mitra

In the water regime of this State the vast masses of glaciers (Zemu, Lhonak, Kanchanjhau) and snow that occur at high altitudes in the north-west, north, and north-east, which are the sources of numerous streams, play considerable role. But no data are available to show that the floods of the last 7 years are due to any large scale recession of glaciers in the recent past. Neither are there signs of recent earthquakes or other major geological upsets on which the blame can be laid. Heavy and concentrated rainfalls doubtless constituted one of the contributary causes, but they must have been apparently assisted by various others, some of which had to do with human interference and the upsetting of the delicate balance that existed between rainfall, forests, soil on hill slopes, river currents and river beds. These will be studied below separately in respect of each Valley.

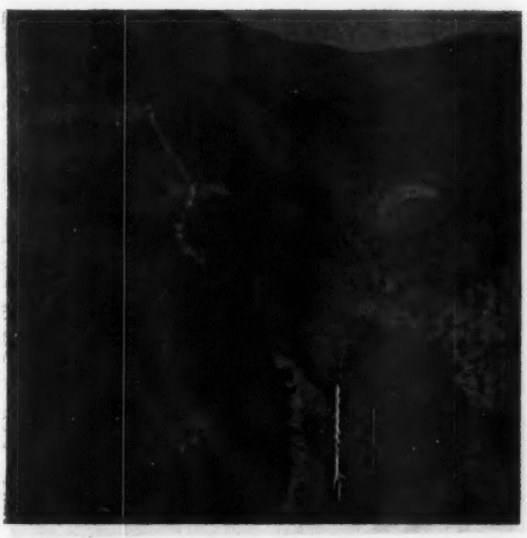
The Lachung Valley

The main rock formation in this valley is gneiss which is fairly stable. Hence landslips are not a common feature. But due to alternate freezing and thawing of water disintegration of rock is extensive on the hill sides between Donkya La and Momesamdong. Glacial moraine deposits of great depth (200′-1000′) are a characteristic feature of this valley. Where hill-sides are steep and the vegetation is sparse these moraine deposits have a habit of sliding down. Typical 'mud flows' of this nature are conspicuous about a quarter of mile north and half-a-mile south of the Chhachhu hot springs. These mud flows descended from the western gneissic cliff which has a slope of 70°; the slope of the ground where the mud flows meet the valley is about 10° while the top portion has a slope of about 35°. The width of these flows is sometimes as much as one mile.

The Lachung Valley between Lachung and Yumthang is characterised by numerous mud flows of this sort which are responsible for the blocking of the river and formation of small temporary lakes. In periods of

Result of bad management of forest gully erosion from 1,000 ft. above river bed as seen from the Tong Dak Bungalow.

Photo—P. K. De



Bare hill slopes on the left bank of the Lachen behind the Chungthang Dak Bungalow.

Photo—P. K. De

Unwise cultivation of hill slopes on the left bank of the Lachen after deforestation. Now abandoned. Shifting cultivation causes extensive damage to hill forests.

Photo—P. K. De

heavy rainfall the natural dams give way and there is a sudden release of the water of the lakes which adds enormously to quantity of water draining off the catchment.

As the gradient of the river is already steep (1 in 16) this exceptionally large stream-flow attains great speed, resulting in heavy bank erosion, which in 1950 reached heights of 150′ to 300′. The locations of heavy bank erosion or slipping down of the bank made up of ancient glacial moraines are given below, in the north-south sequence :—

Serial No.	*Location*	*Height of bank erosion*	*Remarks*
(*i*)	Beginning from Momesamdong and extending down-stream for 2½ miles.	150′	Both banks.
(*ii*)	Cantilever bridge 4 miles below Momesamdong as centre half mile of bank on either side of it (total width 1 mile)	150′	Banks are still vertical and further cutting back may occur.
(*iii*)	1½ miles south-east of Yumthang over a stretch of 1mile	300′	—
(*iv*)	5½ miles south-east of Yumthang (just below Shingha village) for a stretch of ¾ mile.	300′	Banks are still vertical and further slipping may result.
(*v*)	5 miles north-east of Chungthang (beyond Khedum village)- left bank for a width of 1 furlong.	300′	—
(*vi*)	Left bank all along the lower edge of the Khedum village for 1 mile.	—	—
(*vii*)	The right bank below the Byangya and Linteng and opposite Khedum village.	—	Numerous small bank slips.

The enormous quantites of rock material and soil derived from the erosion of the banks and the bursting of the natural dams are transported into the plains and are responsible for the raising of the river bed, thus reducing its capacity to contain large volumes of water during periods of spate.

Sites of 5 lakes formed by the natural blocking of the waterway were found between Yumthang and Lachung. All of the lakes are now dried up. The natural dams of some of these lakes (including the Sebu Chho and two lakes below Yumthang) were the cause of a severe flood in September 1950 which badly damaged Lachung village, resulting in the loss of 10 huts, 6 persons and 60 mules, and brought considerable havoc in the Jalpaiguri District.

From DonkyaLa down to Momesamdong and 1¼ mile south of it the land carries only thin grass ; from the latter point to the cantilever bridge over the Lachung (13,000 ft.) occurs a temperate scrub forest of stunted rhododendrons, barberry and wild rose. Real forest growth starts from this point

The top portion of the hill sides are fairly well covered by Reserved Forests, though even at elevations of 10,000 ft. there are pastures (created by the cutting out of trees) and patches of abandoned cultivation, which are being colonised by rhododendrons, barberries and *Andromeda* (small trees and shrubs) as well as larch seedlings. Typical of the clearances in the Reserved Forest are the Phune Mema and the Shingba locations, around which there is also heavy grazing of cattle in the forests. But for these the Reserved Forests are fairly dense. Below the Reserved Forests line, however, two-thirds of the area has been cleared of tree growth; of this again about a third is under cultivation at present ; the balance is abandoned cultivation which is getting covered up slowly with shrub growth.

The deforested hill slopes of the Sargophui Chu, a tributary of the Lachung, half-a-mile south of the Lachung village.

Photo—P. K. De

Man's imprudent attack on mountaining forests. Steep hill sides between miles 20 & 21 systematically denuded.

Photo—P. K. De

The crops raised are maize, millets and potato; near Chungthang paddy is also grown. The fields are all unterraced. In the Khasmahal area shifting cultivation with a rotation of 4 to 5 years is the common practice. The population being small, however, the damage is not very extensive upto date.

Open and extensive grazing by sheep, mules, yaks and cows in the forests and scrub is the rule. Momesamdong is the biggest yak-grazing centre while the Lachung Village maintains a large number of other kinds of cattle.

Freshly cleared land opposite to Range-Rang Chu.

Photo—T K. Mitra

Ugly scars (of erosion) disfigure denuded hill faces near Lachen village. No marks of ill-health on well clad slopes in the foreground.

Photo—T. K. Mitra

The Lachen Valley

As already mentioned this is the longer of the two streams which form the Teesta. The land slopes into the valley of this river from very high peaks—Donkya Rhi (20,310′) and Kanchanjhau (22,603′) of the southern ridge in the initial westerly course of the river; Chomiomo (22,403′) in the north; Lhonak (22,015′) in the north-west; and Kanchenjunga (28,168′) in the west. In its westerly course the valley is cauldron-shaped, with gently sloping hills ; but from Thangu downwards it assumes the form of a gorge flanked by hills with slopes of 35° to 40°. Well-marked terraces in two or more steps and the U-shaped valley in this region are strong indications of glacial action and formation of temporary lakes in the geological past.

The major portion of the rock in the valley is metamorphic, viz., gneiss, and is fairly stable. Forest occur from the river banks right upto the limit of tree

The revolt of badly treated hills. A rock slip following deforestation on Phyaktuk Peak, left bank of Lachen River, 1 mile north of the Lachen village.

Photo—P. K. De

Festering sores on nature's body which keep on spreading. The landslide above Lingdok village.
(L)—Old slip surface.
(11)—New slips.

Photo—G. N. Dutt

The Bazar at Makao (1,850 ft.). A wise race of men would let the forest come to their very doors and not itch to clear it.

Photo—T. K. Mitra

growth (14,000′), but below the boundary of the Reserved Forests, 70% of the land has been cleared of woods; of this again, about a quarter is at present under actual cultivation, the remainder having got covered up with shrubs and small trees after agriculture was given up due to land-impoverishment.

The following are amongst the most striking features of the Lachen catchment:- (*i*) By far the largest portion of the catchment lies beyond the limit of the growth (13,000′) and even of alpine pastures (16,000′) and consists of exposed rocks and crags or snow-covered ground. A many-branched stream system drains the Lhonak snows in the north-west into the Zemu Chhu, which itself collects water from the large Zemu Glacier in the west, and ultimately falls into the Lachen. The Zemu system does contribute a large quantity of turbid water to the Lachen. (*ii*) Cultivation in the Lachen Valley is all unterraced. (*iii*) Shifting cultivation goes on freely in the forests outside the Reserves, 4 to 5 years being the interval between successive clearances. (*iv*) Forests in the Khasmahal belt are also liable to extensive damage by fire, as was especially noticable at Samdong and between Thombu and Kalep villages. (*v*) Open grazing by sheep, ponies, mules, goats and yaks is the rule is this village—herds of yak, 50 strong each, having been frequently met with by the parties. Lachen itself is a big centre for cattle (with a strength of about 600). (*vi*) by far the most disturbing feature of this valley is the vast slip occurring near the mouth of the Fim Chhu, a tributary of the Lachen which joins the latter about $1\frac{1}{2}$ miles north-west of Chungthang.

The landslide in the Fim Chhu which is said to have occurred in 1948 started from an altitude of 13,500′

A view of the Lachung valley about a quarter of a mile south of Chhachhu. An ancient mudflow (M) which had blocked the valley in the past is seen downstream through the foliage on the right.

Photo—G. N. Dutt

A view of the terrace on the left bank of the Chhateng village south of Chungthang. This was the site of a lake at the time of Hooker's visit in 1849.

Photo—G. N. Dutt

and came down to about 6,000′, depositing enormous quantities of rock and soil debris in the Fim Chhu and the Lachen river. Signs of abandoned cultivation are evident upto8,500′. The area affected is about 2 square miles, and as a result of the slip the Lachen got dammed at this point forming a lake half-a-mile long by 250 ft. broad. This lake still exists, the flow of the Lachen being maintained by a breach in the 50 ft. high dam.

The following is a list of other slips in the valley:-

Location	*Particulars*	*Extent*
39th mile	Soil slip	½ mile × 1 furlong
-do-	Mixed rock & soil	300′×100′
Chungthong Khola	Rock slip	—
Pangnal Chhu	Rock slip	From 14,000′ elevation to 11,000′. About 200 acres.
Chabrur ridge	Rock slip	300 acres (from 14,000′ to 12,500′).
Yulhego ridge	Rock and soil	80 acres in 2 patches; throw considerable quantities of silt into the river during the rains.
Chhenlo Chhu	Rock and soil	20 acres.

The Dikchu Valley

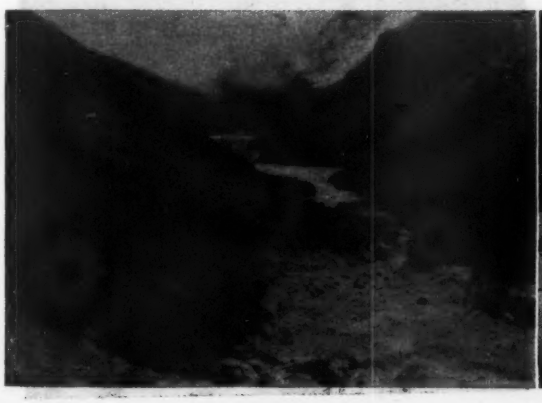
Rising from near about the Chela ridge (15,000′) on the Sikkim-Tibet border and joined by two tributaries (the Bakchu Chhu and the Ohedong Khola) in its course, the Dikchu falls into the Tista at a place called by the same name (Dikchu) about 25 miles below Chungthang.

The slopes of the hills on the left bank vary from 30° to 45° whereas those on the steeper right bank vary from 45° to 60°. There is therefore more extensive cultivation on the left bank than on the right bank. Forests are undisturbed near the hill tops and ridges. But considerable deforesatation for the purpose of shifting cultivation has taken place below. Such cultivation is unterraced. The crops raised are paddy, maize and *kodo*. Paddy forms the major crop (75%). Cardamom cultivation is practised in the *jhoras*. Besides there is open grazing of cattle on the hill slopes.

As a result of all this maltreatment (and with a heavy rainfall, of which there is no proper record) numerous small landslips were noticed in the Dikchu Valley, which occurred between 1951 and 1954.

Mud-flows and land-slides sometimes entirely block a river course forming artificial lakes. Picture shows the site of an old and dried up lake at Phune Khongma, about 3½ miles south of Yumthang

Photo—P. K. De



Scouring of the moraine bank of the Lachung river at Shingba. This was caused by the Sebu-Chho lake burst in 1950.

Photo—G. N. Dutt

The natural dam on the Fim Chhu formed by the the Pemikhangchen landslip in 1948 which now supports five-year old *Utis* (*Alnus nepalensis*) trees. There are many trees yet standing erec in the middle of the lake. Subsequent to its formation the river Lachen cut through the dam below the cliffs shown in the foreground.

Photo—G. N. Dutt

Site of a natural dam in the Lachung about 3 miles from Yumthang; the dam burst in 1950 and added to the intensity of the September flood.

Photo—P. K. De

Bank erosion in the Lachung Valley, 5 miles from Momsondong.

Photo—P. K. De

The Teesta Valley

For the purpose of this note Teesta Valley has been taken to mean the portion below the confluence of the Lachen and Lachung at Chungthang. As already mentioned before, the party reconnoitred this valley between Chungthang (5,280′) and Singtam (1,400′).

Earlier it was pointed out that from Chungthang to Singhik the river has an average gradient of 1 in 30 and from Singhik to Singtam an average of 1 in 120. The parent rock consists wholly of gneiss from Chungthang to Singhik; then it changes to a mixture of gneiss and mica schist upto Mangan (about 2 miles below Singhik), below which it is made up principally of the much softer and more easily erodible phyllites.

Above Dikchu the average slopes of the hills are 30° to 40° and 40° to 45° on the left and right banks respectively, while below Dikchu the slopes on both sides are easier, being 20° to 30° on both banks. From Chungthang to Dikchu the steeper right bank has a forest cover of about 70% while the less steep left bank has only 50% (the rest being cut out sometime or other for cultivation). Below Dikchu the forest cover on both banks is as little as 50 to 20%. Reserved Forests are confined to the ridges, while, in the more accessible areas below, forests are badly hacked out.

Rainfall records are available only for Chungthang in the north and Rungoo in the south where the average annual precipitations are 100″ and 80″ respectively. Agricultural crops are maize, millet, paddy and cardamom. Paddy is usually confined to the lower flats between Chungthang and Dikchu, but below Dikchu it is the major crop. Maize is an important crop throughout the region.

One flood paves the way for another. Heavy bank erosion (in the Lachung Valley) caused by floods worsens the river regime.

Photo—T. K. Mitra

Maltreated hill-sides bare their teeth in revenge. Landslips 6 miles from Momsendong.

Photo—P. K. De

Although between Chungthang and Dikchu unterraced cultivation (except in the case of paddy) is the general rule and shifting cultivation is also prevalent, yet owing to the thinness of the population and the stability of the rock there is not the same extensive damage in the shape of erosion and landslips as in the portion below Dikchu which is more intensively cultivated, albeit careful terracing is done and neat drainage channels covered with vegetation are estabilshed. In the former area, however, especially between Tong and Dikchu cardamom cultivation (which forms 30% of the total crop) is responsible for considerable soil erosion—the cardamom fields being generally located along *jhoras* and kept too thoroughly clean-weeded during the rains.

There are no pasture lands maintained as such. Open grazing goes on freely in the badly cut-up Khasmahal forest lands and scrub. The result of all this improvident land use is the occurrence of numerous landslips and erosion foci, some of which are enumerated below :—

Causes of the Recent Floods

It is idle to attempt to pin the blame for the recent floods on one or two particular factors. What is evident from the reconnaissance survey is that the causes of the floods were a combination of many factors, some of which have had a cumulative effect. Excessive and concentrated rainfall is no doubt always the immediate cause, but without the help of other adverse conditions it could not by itself give rise to such extensive damage. Rock and soil slips, either extensively at particular areas (like those in the Papun Khola, the Rangerang Chhu, and at Ligni in the Teesta Valley; or the Fim Chhu, the Pangnal Chhu, the Chebrur ridge and the Yulhego ridge in the Lachen Valley), or numerous, though individually small, as in the Dikchu Valley, have to take a large part of the blame. Deleterious effects are produced in two ways—(*i*) by the transport of large quantities of detritus along the streams and dumping them in the river bed as soon as the river debouches into the plains, widens out and loses the velocity of current which keeps rock fragments, sand and course soil in movement in the hill portion, (*ii*) by

Location or name	*Nature of trouble*	*Extent*	*Remarks*
32nd mile slip.	Slip composed of loose coil.	500′ 80′	Due to shifting cultivation.
Opposite Tong Bunglow in the Ger village.	Gully erosion in mixed rock and soil, gradually creeping upwards.	—	Surrounding area bare of forest cover because of shifting cultivation
Lower side of Ger village.	Recent slip of mixed rock and soil.	10 acres.	Occurs on a steep slope.
30th mile slip-between 4,500, & 4,000′ contours.	Fresh slip of loose soil and boulders.	300′ 100′	Surrounded by abandoned shifting cultivation now grown over with shrubs.
Vong slip near Vong village (30th mile between 5,000′ and 4,000′ contours).	Old landslip of mixed rock and soil partly covered with trees.	50 acres.	Still active and extending sideways. Top portion had originally been cleared for cultivation.
Rhi Chhu slip (29th mile)	Mixed rock and soil slip	—	The head and sides are still cutting back. Bridle path between 5,500′ and 4,500′ breached.
Mamu Khola slip (4,800′).	Rock and soil slippong down.	—	—
Domthong Khola slip 5,000′ contour (mile 26½).	Mixed rock and soil, partly covered with trees.	10 acres.	Surrounding area is thinly covered with trees and shrubs
Near Kejer village (22nd mile)—along the Kajer Khola.	Slip of soil mixed with gravel.	10 acres.	—
Rangrang Chhu slip between 5,000′ and 4,000′ contours (mile 18)	Soil slip.	100 acres. in several patches.	This sends down a lot of silt into the Teesta.
Between 16th and 17th mile.	Loose soil slip.	500′ 50′	Caused by clearance of forest and cultivation.
Ligni slip (4 miles south Dikchu).	Loose soil slipped down from 4,000′ contour to the river bank through Ligni village.	150 acres.	Angle of slope 30° to 45° This is a very extensive and nasty-ooking slip. There are extensive deforested areas on the hill slopes.
Papun Khola slip between 6,500′ and 5,500′ contours (4 miles to the north of Singtam)	Slip of mixed rock and soil.	80 acres.	This is also an extensive slip contributing a lot of debris to the Teesta through the Papun Khola.

Most of the slips have occurred between 1950 and 1954.

If further unmolested (even after bad use) a protective mantle of vegetation covers up the wounds on the soil. Here is seen a 3-year old *utis* crop on alluvial deposit below Chungthang.

Photo—T. K. Mitra

providing abrading and cutting edges to the streams and leading to extensive bank erosion (as in the Lachung Valley), and (*iii*) by temporarily blocking the courses of streams and forming artificial lakes, the bursting of which in periods of heavy rainfall greatly adds to the volume and velocity of water and vastly enhances its mischief-making capacity (sites of 13 such lakes were found by the party in the course of the Tista, the Lachen and the Lachung).

The bed of the Teesta below the railway bridge at Sevoke has been raised so dangerously high by deposition of enormous quantities of eroded material transported from the catchment of the river and its tributaries that any heavy precipitation in the catchment is almost certain to cause flooding of extensive tracts on either side of the river.

But landslips and soil erosion are themselves the effect of some other disturbances. As has already been observed, there have been in this region no major geological upheavals such as those responsible for the Brahmaputra floods in Assam. Not only the Forest Officer, but the Geologist and Irrigation Engineer have specifically stated that the causes of landslides and erosion in this region were—(*a*) the unwise removal of forest cover on steep hill slopes, (*b*) the practice of shifting cultivation, whereby block after block of forest was cleared in rotation, the land being cultivated without terracing, and then abandoned and left to come up with a scanty vegetation of shrubs or to erode into the valley, (*c*) extensive cultivation of hill-sides (terraced and unterraced) on easy as well as fairly steep slopes, in the more developed southern regions, and (*d*) open grazing of large of herds of cattle in the forest and scrub, which considerably reduces the efficacy of the latter as agents for soil-protection.

There appears to be little doubt that the cumulative effect of these processes over a century of peaceful and steady development and expanstion of human activity in this once remote catchment reached a critical point and started making itself felt since 1948. And considering that similar factors are at work through out the other neighbouring mountain states of Nepal and Bhutan there can also be little need for doubt that that if these processes are permitted to continue unchecked, we shall arrive at a stage (possibly in a century, may be even earlier) when the entire Himalayan tract and the major portion of the submontane region, together with all their magnificent wealth of tea and forests, wild life and scenic beauty will have to be written off as a wasted and destroyed asset.

Examples of human self-destruction resulting from *progress* unlinked with great wisdom and unassisted by scientific observation and properly directed human endeavour are not uncommon in the history of our race. These very processes were responsible for the disappearance of empires and civilization like those of Babylon, Assyria, Persia, Carthage and the highly developed communities that once flourished in Central America, Columbia and Ceylon. The most recent example of such havoc is that of the United States where extensive, country-wide, mechanised lumbering was responsible for large scale erosion, floods, drought and sandstorms etc. which result from outraging Nature. But with a gigantic effort, which included intensive demonstration and propaganda and the covering up of the entire country with Soil Conservation Districts, they have been able to avert disaster which was otherwise too certain.

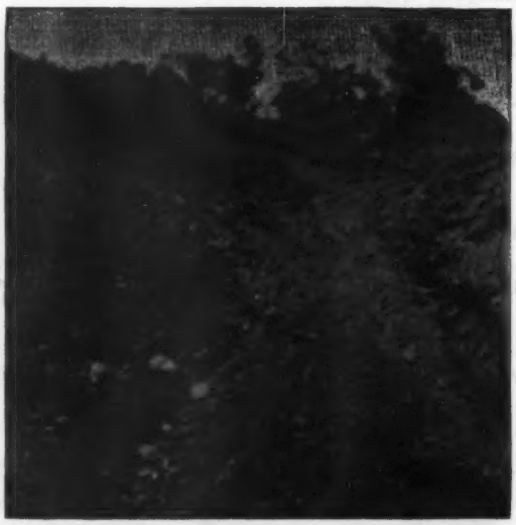
Suggested Remedial Measures

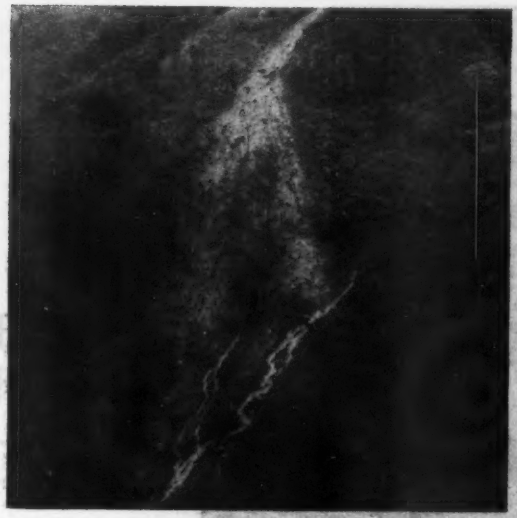
A : Immediate measures

The immediate need is to check the destructive capacity of the current and the volume of water that develop in this river system during times of heavy rainfall. The survey party's suggestion is to

But imprudent humanity keeps on disturbing nature's rehabilitation work and keeps the sore alive. An active landslide in the Lachung Valley.

Photo—T. K. Mitra





Once a landslide starts it creeps into healthy land adjacent to it. Shifting cultivation area in the Teesta Valley.

Photo—T. K. Mitra

construct a number of check-dams, the sites of which are enumerate below :—

(*i*) On the Teesta River near the suspension bridge at Makah—the dam to have a height of about 200 ft.

(*ii*) On the Teesta River about 300 yards upstream of the confluence of the Talung Chhu (between Dikchu and Singhik). There is a constriction in the river here which makes it a suitable site.

(*iii*) On the Teesta River about 800 ft upstream of the Tong suspension bridge. The dam is likely to have a length of 1,500 ft. and a height of 200 ft.

Outraged nature in fiery revolt. The great fim Chu slip of 1948 origin in the Lachen Valley, at the mouth of the Fim Chu.

Photo—T. K. Mitra

A view of the talus fan (T) at the confluence of the Papung Chhu and the Teesta. Debris of the fan had been transported from a land-slide about 500 feet by 100 ft. between 4,000 ft. and 4,400 ft. on the Papung. The slide occurred at a weak foliation dip of the phyllitic strata. The fan measures approximately 600 yds. by 300 yds. The slide material had destroyed the cultivated terrace 100 ft. high, in the centre of the fan. The original terrace (t), representing and old debris fan, is partly preserved on the left of the picture.

Photo—G. N. Dutt

(*iv*) On the Lachen River—The existing natural dam above the confluence with the Film Chhu (north-west of Chungthang) can be strengthened by proper sectioning and provision of aprons. The existing lake will then serve as a flood-moderating reservoir.

(*v*) On the Zemu River near its confluence with the Lachen. This tributary of the Lachen being a mighty, glacier-fed stream, it is necessary to control the velocity and volume of the water it fetches during the season.

(*vi*) On the Lachung River at mile 38¾ (between Chungthang and Lachung villages). Here is a good rock outcrop suitable for the foundation of the dam. The dam will be about 600 ft. long and 150 ft. high.

Other possible sites—Kambor, Pagong and Chungthang (south of Chungthang suspension bridge; the dam is likely to submerge the Chungthang village) in the Teesta valley—were suggested by the Geologist, but not yet endorsed by the Engineer. The Geologist also made mention of the selection of a site at mile 29½ near Geillekhola by Dr. J. B. Auden of the Geological Survey in April 1947, for a 500 ft. high dam of the curved type on the local diorite-gneiss rock. This has also not been referred to by the Irrigation Engineer, probably because of the huge cost it involves.

B. Long-term measures

It is the conviction of the reconnaissance party that engineering works are temporary palliatives and that something more is to be done in order to avert future trouble. The catchment *must* be restored to health in order to (1) decrease run-off, and (*ii*) reduce the load of soil and silt etc. in the streams. If this is not done the dams will be filled up very soon and will cease to function as flood-moderating structures.

A view of the right bank of the Teesta showing the landslides at Ligni. OL—old slip surfaes. D—new slides. Witness the clearances and shifting cultivation adjacent to the slip.

Photo—G. N. Dutt

It is universally admitted that the most effective factor for reducing run off and minimising the silt-load of streams is vegetation. A dense, many-tiered permanent vegetation such as is still to be seen in the Reserved Forests of the catchment is of vastly greater help than the temporary cover afforded by annual cultivation, or the thin and scrappy forests of the Khasmahal which are impoverished by (*a*) unrestricted cutting and (*b*) intensive grazing, or (*c*) periodical clearing for the practice of shifting cultivation.

Cultivation which already loosens the soil and exposes it to the direct force of the rain enhances both run-off and erosion. But unterraced cultivation does the mischief even more effectively, as water runs off unchecked along the slope. Most of the erosion and slips were due to one or more of the following causes :— (*a*) destruction of forests on steep and vulnerable hill-slopes, (*b*) Practice of slifting cultivation, (*c*) unterraced cultivation, (*d*) extensive cattle-grazing, (*e*) extensive cultivation of hill-slopes in one region and (*f*) cleanweeded cardamon cultivation along steepish *jhoras*.

The remedies will obviously be :—

(*a*) Prohibition of forest clearance on steep slopes.

(*b*) Re-afforestation of slips and eroded areas, in order to stabilise them.

(*c*) Increase of total forest cover in order to reduce total run off in the catchment and total silt-load carried by the streams.

(*d*) Prohibition, or restriction, or regulation of open cattle-grazing in critical areas and the encouragement of stall-feeding of cattle, as well as a fairly big scale planting by villagers of fuel and fodder trees and shrubs on their own lands in order to meet at least a part of their total requirements.

(*e*) Effective fire-protection of forests. Fire not only reduces the vegetative cover by killing some of the trees and shrubs, but also destroys humus, thereby spoiling the water-absorbing capacity of the soil and leading to excessive run-off and consequent soil movement.

(*f*) Prohibition of cultivation on hill-slopes steeper than 30°. (In U. S. A. 15° is considered to be the limit for agricultural practices).

(*g*) Stoppage of the ruinous practices of shifting cultivation and unterraced cultivation altogether.

[*Continued on page* 65

Flood Problems of North Bengal Rivers and how to solve them by Model Experiments

By Dr. N. K. BOSE,
H. R. PRAMANIK and N. G. MAJUMDAR

FLOODS in North Bengal were known before, but it is only after the independence that the problem was taken up on a national level. The State Government with the aid of the Government of India has taken up the challenge of the notorious rivers in North Bengal and considerable work has already been done to protect the important public interests in this area. But greater work lies ahead to bring about a long term solution of the whole problem.

The rivers in North Bengal have been found to present very intricate problems. The rivers in this area run over very steep hill slopes before they emerge on comparatively flatter plains, where the important towns and industrial areas are situated. The hill slopes, laid barren through uncontrolled deforestation and grazing, yield huge quantities of boulder, gravel and sand to the running water and these are carried down and deposited on the river bed when the water is no more able to carry them on comparatively flatter slopes. On steep slopes, the velocity of the river is very high and the river stage rises and falls very rapidly. Consequently the river channels are very shallow and unstable. With the slightest obstruction in one course, the river may open out and swing completely to a new course in the wide flood plain. If any narrow bridge is built on any of these rivers unduly restricting the respective waterway the flood discharge cannot pass through the bridge section as quickly as it would have done had there been no such bridge. The flood water piles up above the bridge dropping on the river bed above the bridge the detritus, which it would have otherwise carried down. The bed level of the river above the bridge thus rises progressively with consequent rise in the flood levels resulting in the flooding of areas above the bridge. Ultimately the bridge itself fails by overtopping or otherwise. The flood control of North Bengal rivers is therefore as much the control of the water as the control of the eroded detritus that the water brings with it from the deforested and overgrazed hill slopes.

A permanent solution of this flood control problem lies in a long term programme of soil conservation in the catchment areas of the different rivers and their tributaries aided by flood detention reservoirs wherever feasible. Before any such comprehensive scheme can be prepared, considerable volume of survey and hydrological investigations will be necessary. Survey and investigations to this end have already been taken.

For immediate protection of well developed and prosperous but vulnerable towns of North Bengal, however, remedial measures, which though not so far reaching in nature, can be quickly implemented without waiting for the above survey and investigations, were underatken in a number of cases. Role played by hydraulic model experiments in the implementation of some of these schemes will now be discussed in detail one after another.

Barnes-Domohani Flood Embankment

The biggest river in North Bengal is the Teesta. Originating from the snow covered slopes of Sikkim, it travels through a long and narrow mountain gorge and as it emerges out of the gorge, it fans out into a wide and shallow river on the right bank of which is situated the prosperous town of Jalpaiguri, the heart of tea-growing industry of the Dooars. Opposite Jalpaiguri on the left bank of the Teesta is Barnes the shortest connection between Jalpaiguri and the Dooars. An embankment has been constructed to protect the town of Jalpaiguri from inundation due to floods in the Teesta. About 4 miles upstream of Barnes lies Domohani on the left bank of the Teesta. The embankment of the Domohani-Barnes railway line was breached in 1954 and about 50 sq. miles of cultivated land were flooded by the Teesta. The standing crops in the flooded area were damaged and the inundated agricultural land was all covered with a thick deposit of sand. After the 1954 flood a retired embankment was put up at a considerable distance from the bank, but this embankment also gave way at some places during 1955 flood. After 1955 floods a new alignment of the proposed Barnes-Domohani embankment was chalked out, but it was decided on account of the 1955 breach, not to construct the embankment again without examining the proposal in detail in a hydraulic scale model. The model experiments would be able to indicate the best alignment and the required height of the embankment so that it may be safe against the design flood and also economical to maintain. It would also be possible from model experiments to find the protection works that may be necessary to keep the embankment safe against the design flood. The survey and the hydraulic observations of the river that

are necessary for constructing and operating such a hydraulic scale model, were accordingly taken. The model has been constructed and is being operated now in the River Research Institute, West Bengal. Model results are likely to be made available for construction of the proposed embankment in about a month.

Flood Embankment on the Chel at Odlabari Road Bridge

The river Chel is a tributary joining the Teesta after the latter emerges from the gorge. The Chel crosses at Odlabari the Assam link railway line and the National Highway from Siliguri to Cooch-Behar. The road bridge on the Chel at Odlabari has been constructed about 200 ft. downstream of the existing railway bridge. To protect the national highway on the left bank of the Chel just above the road bridge an embankment on the river side of the road following the alignment of the national highway was proposed and partly constructed in 1954, but was breached during the flood of the same year. An alternative alignment of the embankment much shorter than the original alignment was then proposed in continuation of the left guide bank of the railway bridge gradually restricting and guiding the river flow on the left bank through the railway bridge. In both the alignments, the upstream end of the embankment was tied to the same high point. On account of the uncertainty of the methods of computing flood levels above the bridge with the proposed embankment in position, a very large factor of safety is to be allowed in computing the height of the proposed embankment at different points and considerable economy can be effected if the exact water levels for the design flood at different points of the embankment is correctly known. The best tool for finding out the correct levels and the proper alignment of the embankment being the system of model experiments, survey of the river for a length of 10 miles and observation of the gauge and discharge of the river in this reach were done and sent to River Research Institute for conducting the model experiments. Sufficient discharge and gauge observation data could not however be taken to estimate the maximum probable flood discharge at the bridge site. As such the estimation of the maximum probable flood discharge was considered impracticable. For testing the proposed designs in the model, the maximum discharge was taken to be the discharge that can safely pass through the bridge. The model of the Chel river above the road bridge has been constructed in the River Research Institute and the two alternative alignments of the embankment are being put to test in this model under the severest condition when the water level reaches within 3 ft. of the bridge girders. The alternative alignment which gradually restricts the river and guides the flow on the left bank smoothly through the railway bridge, has been found to be the better alignment. Detailed recommendations of the model experiments will be available soon.

Flood Protection—Siliguri Town

The town of Siliguri is situtated on the left bank of the river Mahananda, which is spanned by a road bridge near the heart of the town and a railway bridge a short distance downstream. The river has a tendency to flow along the left bank above the road bridge which has resulted in shoal formation on the other bank. Like other hill streams in North Bengal, this river also is shallow and flashy in nature. During floods, the velocity in the river is very high, though the river rises and falls rapidly. Taking advantage of the shoal formation on the right bank, the railway authorities have gradually encroached on the river by constructing and consolidating railway sidings on the sand bar on the right bank above the road bridge. As a result of this, the river cannot cut through the sand bar even at high stages and there has been greater concentration of flow on the left bank above the road bridge. The heavy floods of 1954 so severely eroded the left bank above the road bridge that the authorities undertook a scheme of training the river for stopping the erosion and chances of outflanking of the road and railway bridges. The proposal of the Irrigation and Waterways Directorate was to provide heavy stone pitching over the affected length of about 1300 ft. on the left bank supported by additional protection of short length (25 ft. to 50 ft.) permeable salbullah spurs spaced about 50 ft. apart along the whole length of pitched bank. It was decided by the Irrigation and Waterways Directorate that before taking up this protection work, the scheme should be tested for its efficacy in a hydraulic model in the River Research Institute.

The suvey of the river and collection of gauge and discharge data, necessary for undertaking the model studies, were completed and model studies were started in the River Research Institute in January 1955. The experiments showed that the encroachment by the Railway authorities on the right bank had really aggravated the situation. The scheme proposed by the Irrigation and Waterways Directorate was found to afford local protection to the affected portion but it could not correct the flow concentration to any extent. The nose of the salballah spurs would be very difficult to maintain when placed in the direct line of the attack, as there will be considerable scour at the nose of the spur and the salballahs driven even to the maximum extent possible may be undermined.

A better scheme of permanent remedy was evolved from the model tests. This consisted of constructing only three strong stone spurs properly designed and spaced on the left bank, one of the spurs having a T-head on it. With these spurs no pitching of the affected portion of the left bank with heavy stone would be necessary. With this system of spurs, the river flow would be corrected and shifted away from the left bank so much so that the distribution of flow through the two bridges would be uniform and there would be very little danger of outflanking of the bridges. With this scheme maintenance of the protection works would be comparatively easy leading to a better guarantee of protection to the interests concerned.

The scheme evolved from model studies could not however be implemented before the 1955 flood season. The original proposal of bank protection with stone pitching aided by small salbullah spurs could however be completed before 1955 flood and is being maintained now.

Flood Protection—Alipurduars Town

The town of Alipurduars is situated on the left bank of the river Kaljani in North Bengal. On account of comparatively flatter slope of the flood plain and friable soil, the river has formed a number of mean-

dering loops here. The town was badly flooded during 1954 floods and a scheme of flood protection by constructing embankments was taken up. The upper part of the town was protected with about 2 miles of heavily protected embankment before 1955 flood season. The construction of embankment in the lower part of the town was deferred for the next working season. Meanwhile another proposal was submitted by the Superintending Engineer, North Bengal Circle, to make a pilot cut across a horse-shoe loop to divert the river through this cut away from the main town. If this cut could be developed, the river would stop flowing through the horse-shoe loop and the town could be protected by a very short embankment along the new straight channel away from the town. This proposal of short circuiting the horse-shoe loop was proposed to be studied in a model.

The model of the Kaljani river was therefore constructed in the River Research Institute after the necessary survey and hydraulic data were obtained. The points to be studied in the model were as follows :—

1. Whether the pilot cut for short-circuiting the loop would develop without closing the loop channel.

2. If the pilot cut does not develop without closing the loop channel, whether it would develop after closing the loop channel.

3. If the pilot cut is allowed to develop, how it affects the river regime above and below.

The alignment and dimensions of the proposed pilot cut was supplied by the Superintending Engineer. About 1500 ft. upstream of the proposed cut, there is a railway bridge over this river which is one of the vital links in the rail communication of North Bengal. A road bridge is also under construction above this railway bridge, the piers and abutment having been completed. The model experiments showed as follows :—

1. The pilot cut would not develop unless the loop channel is closed.

2. If the cut is allowed to develop with the loop channel closed, slight changes occur in the river regime upstream and downstream of the cut. The railway bridge which at present experiences heavy attack on the right abutment and pier, is likely to face a bigger attack on the right side if the river is diverted through the cut.

Considering the safety of the existing railway bridge the scheme of short-circuiting the horse-shoe loop was not pursued further and the alternative scheme of protecting the town from flooding and erosion with embankment along the left bank of the horse-shoe loop was ultimately taken up and completed.

Continued from page 46

Soil Erosion and Silt Problems: Role of Forestry and Soil Conservation

increase the application of forestry has perforce to be restricted to such areas where even conditional cultivation may not be permitted. Further, the form of forestry to be practised in any particular locality must be based on a very thorough survey and on sound planning. Where soil disturbances have been heavy there can be no planting until certain forest engineering works have been carried out and a reasonable degree of temporary stability restored on the hillslope. The choice of species is another item which needs a good deal of judgement for in addition to the type and kind of soil, rainfall and altitude, the commercial value of the species, immediate or potential has to be considered, and this is one point to which the author's attention was particularly drawn by the Chief Secretary of Sikkim sometime ago. A distinction has to be made between deep-rooted and surface-rooted species for while the former will provide reinforcement to the soil mass the latter will hold sheet erosion in check. All members of the Gramineae (grasses) are surface-rooted, and so are many trees such as Ficus spp, and a grassland well mained is an effective buffer against sheet erosion. Owing to its multifarious uses and its rising demand for paper pulp the claim of bamboos, which are suface-rooted, is worth the consideration, and particularly so the case of the single-stem type of bamboos which lend themselves to the easiest form of management, and have an intricate root system provided by long interlacing rhizomes.

Continued from page 62

Reconnaissance Survey in the Upper Valley of the River

(*h*) Restriction of cardamon cultivation to slopes not exceeding 25° (I should have preferred the upper limit to be 20°, considering that such cultivation is mainly along *jhoras* which are more vulnerable than ordinary hill sides as they are water-channels, where the erosive function of running water is very active). Also such cultivation should be restricted to the sides of the *jhoras*, leaving sufficient cover on the *jhora* beds.

(*i*) Restocking of the derelict portion of the Khasmahal forest belt with tree species.

It might appear that too much emphasis has been laid on the forest cover in the catchment. But the main factors to be considered in this region are :—

(*a*) High annual rainfall and intensity of particular storms.

(*b*) Steepness of hill-sides.

(*c*) Erodibility of the soils derived from phyllitic strata.

The only answer to these forces of imbalance is the stabilising effect of a many-tiered forest such as held the hill-sides and contributed to peace and harmony in this catchment before the advent of man. Since civilised existence is not possible without disturbing nature, it is necessary to see that where such difficult factors exist, the disturbance is well-planned and provides suitable measures for keeping the destructive forces in check as well as for giving a chance for recuperation from the efforts of inevitable damage.

Problem of Flood Control in the Keleghai Valley

By E. A. R. BANERJI

KELEGHAI is a river which has its origin in Dhudkundiof Jhargram P. S. (Midnapore district) and passes through or along the boundaries, of Kesiari, Kharagpur, Narayangarh, Potashpur, Sabang, Bhagabanpur, Moina, before it falls into the Haldi river. In its upper reaches it passes through moderate undulating country until reaching Kesiari P. S. after which it becomes fairly flat. In this course it is fed by a number of tributaries from the North as well as from the South. During dry months there is little water in this river, but during the monsoon the uncontrolled run-off from the extensive bare catchment area swells the river unduly and floods cultivated areas in the lower valley. The principal reason for this is the almost complete deforestation of the upper catchment and heavy grazing which is still practised, hardly allows any vegetal cover to regenerate and check the run-off. Every effort has been made in the past to tackle the flood problem of this river from engineering side, such as by widening and deepening the river, strengthening the embankments, digging diversion cuts etc. but none of these measures proved effective. The possibility of flood moderation by construction of reservoirs in the upper catchment was also considered, but due to the absence of suitable sites for a dam of even moderate dimension, these have been ruled out. Besides, even if a dam is constructed it will not solve the problem permanently, as such structures under the existing conditions of high silt load will have a very short life.

Some years back the Land and Water Utilisation Board of the State while considering the question of taking up soil conservation work in the State, thought that the Keleghai basin where all engineering efforts have failed offered an ideal area for testing the effect of soil conservation method for flood control. If found effective it would also demonstrate the value of soil conservation to the people of the country and prepare the ground for taking this up on a national scale for all such problem areas.

The Catchment of the River

The land capability survey carried out showed that the upper catchment comprises about 288 sq. miles and is in the main problem area in this river basin. This can be classified into four prominent zones: viz:

(1) area between 200 ft. to 250 ft. contour
(2) ,, ,, 150 ft. ,, 200 ft. ,,
(3) ,, ,, 100 ft. ,, 150 ft. counter
(4) ,, below 100 ft. contour.

Out of these the first three are the areas where soil erosion and heavy run off is taking place. The fourth zone mainly consists of cultivated areas where paddy is the only crop grown at present. These paddy lands being bunded in the usual manner for paddy cultivation, do not allow very much of erosion, but the productivity is low due to poor management. The approximate area of such cultivated land is about 120 sq. miles and the soil depth varies from 2 ft. to 5 ft. depending upon its situation.

The lands which fall between 100 ft. to 150 ft. contours are approximately 80 sq. miles. Here also some cultivation is practised, but in a very scrappy manner and once in three years, particularly on those lands where some soil still exists. The soil depth in this area varies from 0 ft. to 4 ft. and lie on 2% to 3% slope. Portions of this area which are not cultivated are, however used for grazing purpose, but the grazing is done very heavily, not allowing any vegetal cover to regenerate properly.

The above leaves only the area which lie between 150 to 250 ft. contour comprising approximately 88 sq. miles. On some portions of this area attempts are made to cultivate but quite unsuccessfully and the sporadic opening of lands for cultivation purpose exposes them to increased erosion hazards. The major portions of this area, however, have either patches of degenerating forests or bare lands with meagre grass cover subjected to heavy grazing. These lands also have a slope of approximately 2% to 3% but in many places the soil cover has completely disappeared and the parent rock material is exposed. Although active erosion is now taking place in this area, it is more of the nature of sheet erosion. This is due to the low slope of the area; otherwise plenty of deep gullies would have been formed. Some small gullies in many places have, however, made their appearance and are gradually deepening.

The Problem and its Solution

The condition of the catchment at the source of the

Keleghai River where lower catchment begins during dry season.

river, therefore, shows that there is hardly any chance for the rain that falls on 88 sq. miles of area to get soaked, and completely runs off the catchment causing further erosion on its course. Apparently this is how the Keleghai river itself actually originated and is now gradually lengthening in the upper reaches by the deepening of the gullies and adding to the flood problem in its downward course. The main reason for the creation of this situation is deforestation which has been going on in this area from a long time and during the last war this was intensified due to the construction of an emergency air strip there. Now the area is completely bare of forest cover. This created the ideal condition for havey erosion and the cumulative effect of disturbing the nature's balance is now causing floods in the lower valley. The engineering operations that were carried out thus proved ineffective against the gradually increasing volume of water from the catchment due to gradually complete deforestation and the increasing silt load brought down, which is continually rising the bed of the river. Another tributary of this river is also for this reason now in its formative stage, a few miles downstream.

The fact that the river existed from a long time in its lower valley and only in recent times has started lengthening in the upper reaches when this catchment started getting deforested, gives ample support to the belief that floods in the lower valley is entirely due to the subsequent baring of upper catchment. If the run-off in the upper catchment can, therefore, be controlled there is good reasons to presume that the flood problem of this river can be substantially moderated, if not completely controlled.

The checking of run-off will also put a stop to heavy erosion that is now taking place in the bare catchment area and will ultimately heal up the lands there, making them once again fertile and productive.

Method of Approach

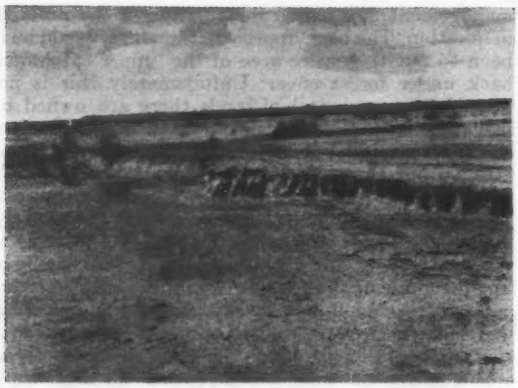
A soil and water conservation approach which has now been visualised for tackling flood problem of Keleghai basin, is essentially an approach which aims at restoring natural condition which has been upset by man. It also aims at utilising lands according to their capabilities. In this case it is quite clear that heavy deforestation of the upper catchment which was at one time completely covered with forest, and its bad management, has led to the creation of the problem in question. The best, approach, therefore, would have been to put the entire area of the upper catchment back under forest cover. Unfortunately this is not possible, as good deal of lands there are owned by private persons and have also been put under various kinds of uses, such as grazing, periodical cultivation etc. To put the entire area of the upper catchment back under forest will also mean depriving the local people from making some immediate income from the lands. The forest also takes about 20 to 30 years to regenerate, and during this period there will hardly be any income from these lands. Again, according to new rules there cannot be any private forest in the state. As such, complete afforestation of the area will mean acquisition of lands for putting under forest which will const a lot to the State. With all these difficulties the only approach on the basis of soil and water conservation methods left open, appears to be to put a forest belt on the higher contour level of the upper catchment and to make use of the lands below according to their capabilities by suitably contour bunding. Under such a plan certain patches of the area could also be put under permanent grass and controlled grazing practised on them. These soil conservation operations, it is presumed, will help considerably in checking the run-off that is now taking place and causing erosion and floods. They can also be carried out on lands which are privately owned, as there will be no question of depriving the owners from their rights. Rather the measures proposed on the other hand, will improve the lands which are now lying fallow or are periodically cultivated and will make them more productive, as the water that is now running off the catchment will be held and soaked in, which in its turn will help to increase the capacity of the lands to retain in vegetation.

The plans for the treatment of the catchment areas lying between 100 ft. to 250 ft. contour, are thus visualised to be the most effective means for controlling the erosion in the catchment and for tackling the flood problem in the Keleghai basin.

Merit of Soil Conservation Approach

Whenever flood control problems are considered, the general reaction is to think of some engineering structures. It is surprising that is this age when we are making tremendous stride in scientific knowledge and human ingenuity, we hardly think of other devices

Keleghai upper catchment showing sheet erosion and remnants of former forests.



Keleghai upper catchment—sheet erosion and gully formation.

which could also be useful and perhaps much more effective than engineering devices for control of floods. Along with the basic sciences we have also made great advances, in applied science, particularly in our knowledge about soils and their management. To-day we know that the soil is the main source from which ultimately everything is developed; and how essential it is to preserve this in the national interest. From our knowledge about soils we have also learnt how to preserve them and how by their proper management we can solve flood problems in a better and more efficient and permanent way than by engineering structures. This is also the nature's way. The engineering methods that we are adopting, on the other hand, aim at forcing nature to subjection, the soil preserving approach or soil conservation method tries to appease nature for the benefit of man.

In order to appreciate this it is necessary to analyse the causes of flood. This is, however, not difficult. In river valleys where floods occur, it is a well recognised fact that this is due to excessive run-off of natural precipitation in the catchment area when condition for interception is wanting. This condition is the natural forest cover which is supposed to intercept the rain water and soak it into the soil. The soil cover also protects the soil from being beaten by the rain and dislodging the soil particles from its proper position, which is erosion. When this forest cover is removed by man due to various reasons and if not replenished, it creates ideal conditions when there is nothing to intercept the rain that falls and it thus completely runs off the catchment, and in its wake brings about erosion. When the land thus remains in a neglected condition for sometime, both run-off and erosion increase at a tremendous rate as and both are complementary, bring about floods below the catchment. Thus in the analysis of the cause of floods we have to bear in mind that water in motion flowing over raw soil is a continuing peril and its total destructiveness always increases if factors for interception are not created. Looking at it from the engineeering aspect only we can create the factor for interception by some structures like check dams etc. This will no doubt be effective, but the question is for how long? Simple calculation on the basis of silt load and the erosive effect of the run-off on a bare catchment area easily shows that these dams cannot last long if the erosion is also not stopped. The reservoirs on these dams will get filled up soon and condition will become similar to what was in the beginning of the construction of the dams. Such engineering structures, therefore, can be regarded only having temporary effect and all the money spent for their construction will become wasted if the erosion is not stopped.

In all flood control work, therefore, the checking of erosion is also of vital importance. When the flood intensity is of rapidly mounting nature this is all the more necessary. It only gives an indication that structural work alone can never bring about flood moderation. The erosion problem also requires to be tackled immediately. For tackling this erosion problem comes the necessity of soil conservation.

Another advantage the soil conservation approach offers in flood control work is that by creating conditions for the water to soak into the soil, we also create enormous underground reservoirs of water which are are far better than the exposed reservoirs of check dams which are subject to evaporation. The underground reservoirs can be tapped conveniently at any place and according to our needs, and this water when it comes out again from the soil, will be free from silt and suitable for all kinds of use.

Again, if soil conservation is adopted in time on areas which are vulnerable to erosion we can also without much expenditure check future disaster which can even ruin a civilisation as it had happened in the past in many countries.

This is thus an ideal approach which deserves careful consideration of all concerned with flood control problems, and is also the only approach which can be regarded as less costly and at the same time can bestow permanent benefit. It is unfortunate that although the importance of soil conservation work has been talked about so much lately, it has still remained in the nature of soil conversation rather than soil conservation. What is advocated is a sincere and earnest consideration of the possibilities of soil conservation as an approach for permanent solution of flood problems.

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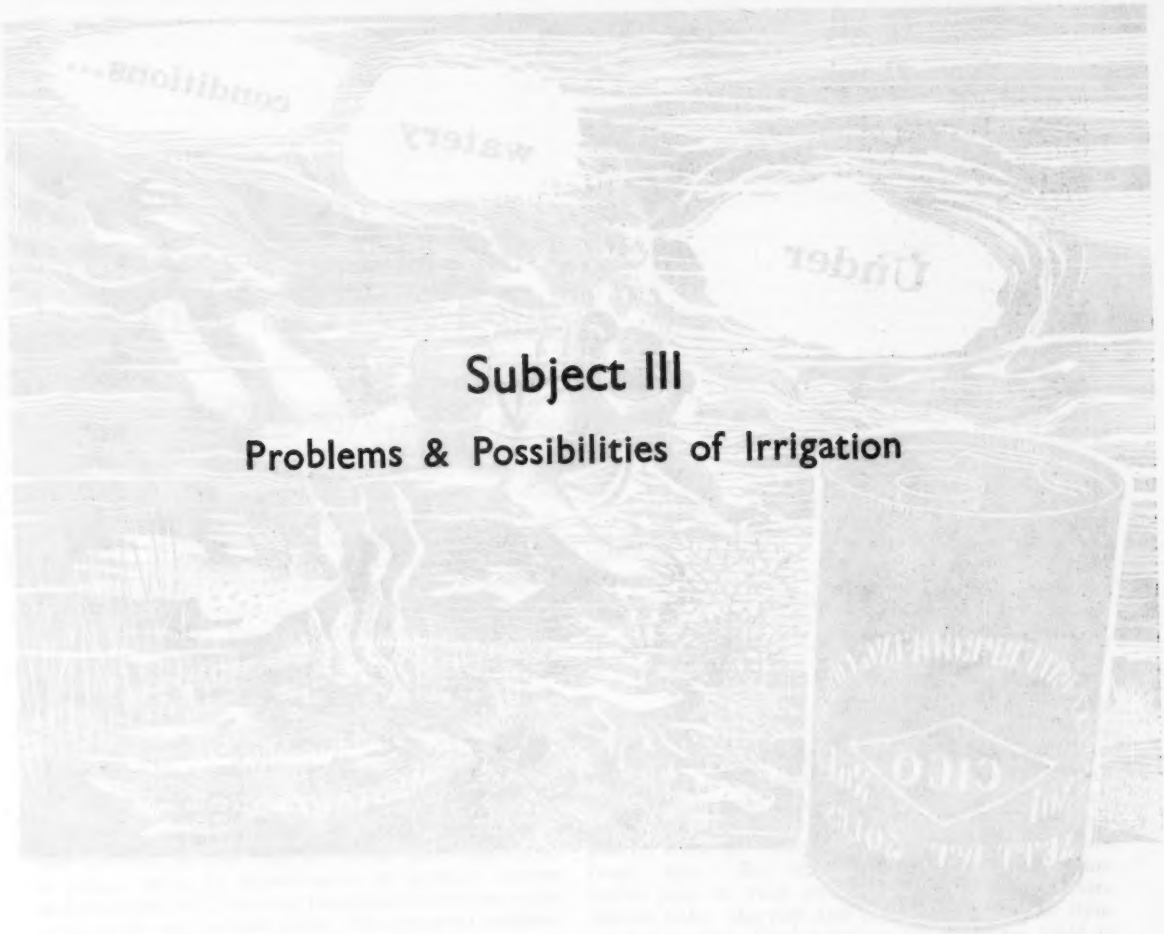
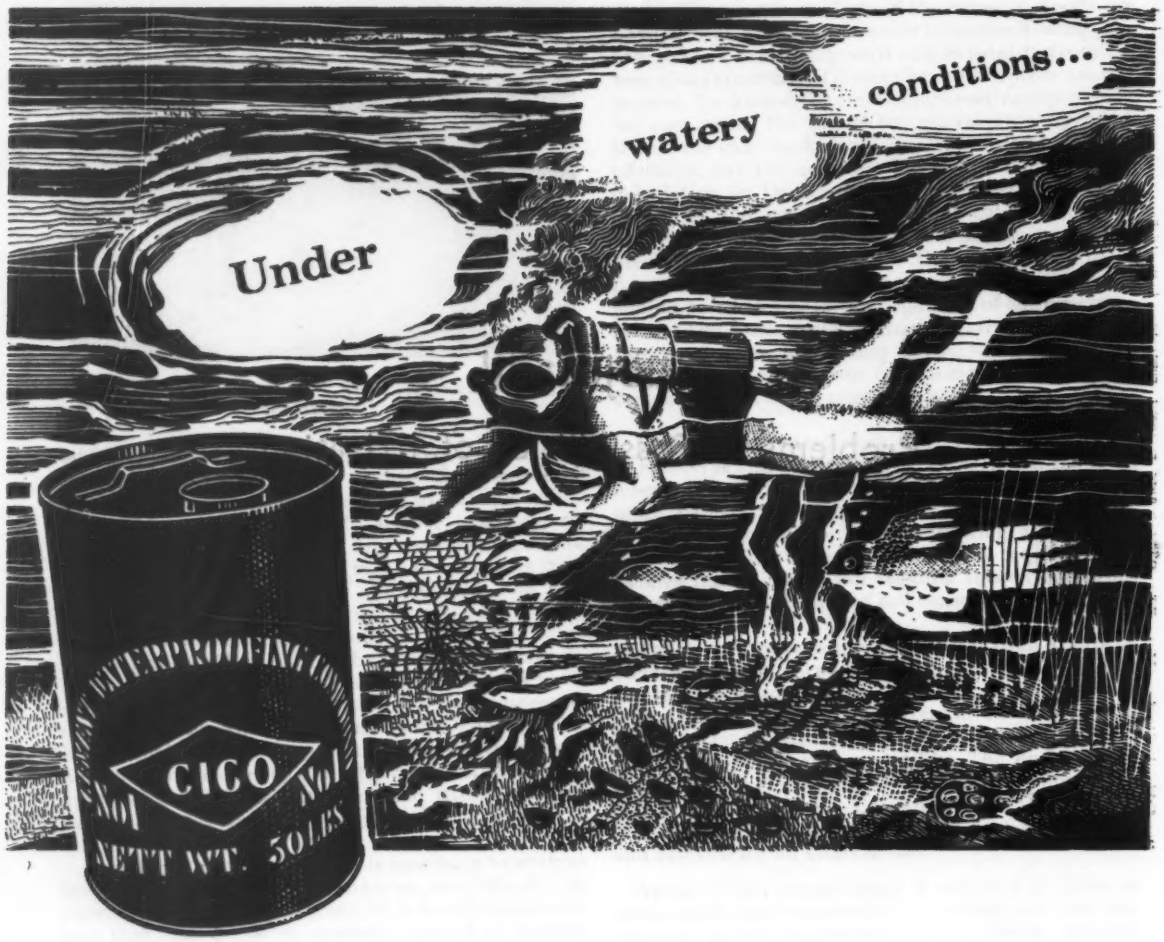


Subject III

Problems & Possibilities of Irrigation



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Problems and Possibilities of Irrigation in West Bengal

R. B. CHAKRAVARTY

PREPARTITION Bengal covered a major part of the Gangetic Delta where not only the lands are fertile (and the fertility is maintained by deposition of silt from annual floods) but the rainfall is also sufficient for growing of paddy (the principal food crop) and jute (the foreign exchange earner). This resulted in the quick development of Calcutta as an industrial area in Bengal with a large population and several jute mills and other factories on the banks of Hooghly upstream and downstream of Calcutta, with the partition, however, this Bengal has been truncated by taking out most of the deltaic agricultural tracts (now in East Pakistan). This has not been the end of the troubles as the influx of refugees from East Pakistan is almost continuous which is increasing the population of the State now known as West Bengal substantially. The population in the industrial area of greater Calcutta is also drawing more and more industrial labour from all parts of India and this has aggravated the problem. Apart from this the birth rate is still more in the area than the death rate (the latter is falling owing to improvement in medical science and discovery of life saving medicines) like most other areas inside and outside India. The essential problem (if not the main) here will, therefore, be the question of finding food for this ever-increasing population. The possibility of increasing the agricultural lands further has almost reached the limiting stage. Accordingly the only way out will be to increase the yield from whatever land is available for cultivation.

Soil forming the earth's crust possesses the property of being dissolved in water slowly but steadily. This results in plant food being available year after year, and owing to this a land is normally suitable for cultivation permanently. So far in most areas this release of plant food from the soil (with the addition of small quantities of locally available manure) has been able to maintain yield of 15 to 24 maunds from can acre of average paddy land. This yield, however, may be substantially increased by proper manuring and seed selection.

The growth of a plant, like the growth of all organisms, is a very complicated process. But one simple feature in the mechanism is the way in which food is taken by the plant. This is done by the osmotic action which induces a pressure from a weaker solution towards a stronger solution. Inside the plant the solution gets stronger by loss of water from its leaves by transpiration. The solution held in the soil is normally weaker and, therefore, enters the plant through the root cells and thus provides the plant with food. To enable the plant to draw its food from the soil, therefore, presence of sufficient water to make the solution weaker than that inside the plant is essential. Otherwise with a stronger solution outside, the fluid inside the plant would come out, destroying the plant. It follows that more water is necessary with increase in manure.

Normally the total monsoon rainfall is sufficient for growing paddy in any part of West Bengal but the distribution in most of the area is erratic and there are periods of droughts occasionally even during the monsoon months. Besides, paddy requires some water during the flowering time (October for Aman paddy) when the rainfall is usually very small. Apart from this, the start of the monsoon rains varies year to year and, therefore, the cultivators cannot take the risk and plant their crops in time for full growth. Seed selection for optimum yield is not also possible unless the amount of water to be added to the field is known. All these show to the necessity of irrigation even in a fairly good rainfall area. Of course, the increase in yield owing to irrigation will vary from area to area being small in a place where soil can retain moisture for a longer period during droughts or during the flowering season. Although canal irrigation water brings sometime soil particles and thus helps in supplying plant food, the importance of irrigation lies mainly in its ability to make the soulution of plant food (dissolved from soil particles as also from the manure added) in the root zone weaker than the solution inside the plant. For optimum growth addition of manure is essential and irrigation being a sort of catalytic agent which enables the plant to take the food in. Normally cultivators here are poor as also conservative. There is no organization either to teach the cultivators about scientific cultivation taking advantage of the irrigation. Even many amongst the educated people try to assess the benefit to irrigation by comparing yields in irrigated and non-irrigated fields, not considering the fact that the real benefit from irrigation is in its ability to present the manure in a suitable form for being taken in by the plant. The cultivators, therefore, hesitate to invest money on manuring properly even when irrigation water is assured. It takes them a long number of

years (after irrigation is made available) to get into the habit of using even a moderate quantity of manure. Very few cultivators have the scientific mind to obtain the optimum yield from their fields. Along with irrigation, therefore, demonstration of the scientific method of cultivation is essential if optimum results are desired. This will not only increase the yield but would enable the cultivators to know the benefit quickly and thus the popularity of and the demand for irrigation would increase.

At present a cultivator in this country grows his crops to meet his own modest requirement (of food and cash money) and therefore he is not particularly interested in obtaining anything more. The interest of the country suffers on this account. Steps should therefore be taken by which a cultivator may be made to attempt for optimum results. He sould be compelled to grow two (or three) crops where it is feasible to do so. The other alternative idea is to make the tenancy of a land for particular crop season so that one party may grow the crop during the kharif season and another during the rabi season. The idea should be to get the maximum out of irrigated land, and this would not only increase our agricultural produce and keep landless labour in employment through the years but would increase the national wealth quickly. Good marketing facility is however essential if it is desired to inspire the cultivators to grow the optimum.

Although the stage appears not to have reached as yet, it may so happen that the food grown may be surplus to our requirements. Such a condition may bring down the price of crop very much and a cultivator will naturally be reluctant to spend money on manuring. With good marketing facilities and the state assurance of a reasonable price for the crops this condition may be avoided. If a move is made at such time it should not be difficult to export the excess crop. But this excess is essential even if it be necessary to waste the excess to safeguard against occasional failures and to remain prepared in advance for the growing population.

If the yield of the land could be increased it should be possible to spare some land for pastures which is so very essential for growing dairy produce. Some paddy lands may also be cultivated with cash crops like jute, sugarcane, oil seeds, etc. Fruit growing is also paying although normally a cultivator is reluctant to undertake this as the returns are delayed. (For this it may require state farming at least in the initial years). There should therefore be no apprehension from the point of view of overgrowing ; on the other hand the present generation would be failing in their duties if they do not prepare for the requirement for the generation to come.

From the point of view of irrigation West Bengal may be divided into four zones (*i*) Western Zone (*ii*) Southern Zone (*iii*) Northern Zone and (*iv*) Central Zone.

Western Zone

This area covers the Birbhum district, Bankura district and the North-Western part of Burdwan and Midnapur districts. The Purulia area will come within this zone. In most of these areas the soil has very little water retentive capacity and surface being undulating the precipitation drains quickly into lower areas and gutters known locally as jhors or kandars and ultimately into drainage streams. In West Bengal the necessity for irrigation is felt more in this area than in any other place. The soil being porous the land is suitable for irrigation. The Mayurakshi Project (recently completed), the Durgapur canals (including the Damodar Canals) and the Kangsabati Project would command a major part of this zone. There are many smaller irrigation systems also in this area, viz. Bakreswar Irrigation Scheme, Midnapur Canals, Damodar Canals etc. Even with these schemes much of the area will be left without irrigation for which only comparatively smaller schemes will be suitable. Some part of the Purulia area may require irrigation from the Kangsabati.

The 3 major schemes mentioned above will irrigate a total of about 2.4 million acres which along with the irrigable areas in the other smaller schemes represent a fairly high proportion of the land in this zone. For the remaining area comparatively smaller schemes will be feasible. There are small streams all over the area but as the discharge is not perennial storage works will be necessary in most cases. In this zone the main problem now will be to educate the cultivators in scientific methods of cultivation, including crop and seed selection for optimum return.

Southern Zone

This covers the district of 24 Parganas, part of Hooghly, Howrah and Southern part of Midnapur district. Here the soil being alluvial, it possesses more retentive capacity and irrigation is not much in demand, but in some part of this zone irrigation will be necessary if a second staple crop is to be assured. The best source of irrigation of these areas is from wells or tube wells and pumps are to be used. For this area good drainage is required for increasing the yield, otherwise the excess salts do not get the chance of being drained away and with constant evaporation salt concentration takes places resulting sometimes damage to crops. The areas in the lower deltaic tract is to be protected against inundation by saline water which makes a land unfit for cultivation for the next 2 or 3 years. The practice followed by Zemindars and cultivators consisted in enclosing lands by embankments along side rivers and draining the land by sluices operated during the ebb tide. This premature reclamation usually results in prevention of further raising of land and some time a portion of the land is left too low even for draining at ebb tide. The courses left for reclamation of such lands are :

(1) Dredging one part and raising another part with dredged material.

(2) Dredging adjoining rivers and raising the land with dredged material.

(3) Pumping the area all the time.

Each course has its own merits and demerits but dredging and filling is usually too costly for use of the land for agricultural purposes. With the development of electricity, however, it is possible to take recourse to pumping as is evidenced by the success of Sonarpur-Arapanch Scheme.

[*Continued on page* 78

Problems and Possibilities of Utilisation of Irrigation Waters

By S. GUPTA

IRRIGATION in West Bengal almost entirely connotes the irrigation of rice, the staple crop, which sustains the population.

The irrigated rice in this context falls into two categories :—

(*i*) the principal kharif Aman monsoon (late autumn) kind. For this seedlings generally dhulot sown are raised during a six week period preliminary to transplantation in prepared and puddled fields from early July to mid August, extended often to the end of August. The harvesting takes place in December and early January.

(*ii*) the secondary early Aman, (locally called Aus) variety, also raised and transplanted at the same time but maturing from the end of October to the beginning of November.

The broad-cast varieties or true Aus, maturing in August or the Boro paddy grown in winter under irrigation, have been rarely in evidence in the irrigated areas.

It is a paradox that though this rice is grown during the season of maximum rainfall, it still needs irrigation. The reason is that the rainfall itself is variable both in quantity and in distribution. But the water requirements for paddy follow more or less a set pattern. While the excess rainfall at anytime serves no useful purpose, if it is not actually harmful, deficiencies must be made up if proper cultivation has to be ensured. The object of irrigation is to ensure supplies of water as and when required for the agricultural processes so that not only the crops are protected but also to augment the yield that irrigation, particularly from silt-laden river supplies, can ensure.

As against a normal rainfull of 53″ during the year in one area, the normal monsoon precipitation may be:—

July	*August*	*September*	*October*	*Total*
12″	11.75″	8.50″	3.5″	35.75″

The minimum in any month, however, may be as low as 50% of the normal. In a very bad year the rainfall in each month may be 30% to 50% in deficit.

Given proper distribution, a total supply of about 25″ may be sufficient for raising a successful harvest. The optimum requirement would be of the order of 40″. In any case quantity and distribution must both be ensured. This will go to show the necessity for ensuring supplementary irrigation.

On the other hand, when the natural supplies are adequate, the silt-laden water still helps to increase the yield by enriching the soil. Another effect of flowing river water would appear to be to keep down the acidity of the soil and inhibit the growth of weeds and pests, all inimical to the prospects of a good harvest.

Experience has shown that the maximum water requirements in the area correspond to maximum duties of 90 for July and August, when the requirement is the highest and of 120 in September and October, when in the growing and maturing stages, the requirement is less. It is seen that excessive water at this stage may prevent an early harvest.

The rivers in the area have a very variable discharge. If the natural flow had been the criterion, the area of any scheme would be drastically curtailed as the low discharges in the two critical stages of July and October—particularly the latter—would have to be the basic dependable supply. Therefore, storage, so as to have water at all times to meet any critical requirements for a much larger area ready at beck and call to help meet emergencies, is needed. The operational characteristics of such a project are in view.

The irrigable area spreads over large and distant areas, served by many canals. Week to week, day to day assesment of the water requirements is made, having regard to nature of soil, rain and moisture conditions and the state or stages of cultivation. This is converted into terms of discharge in cusecs canalwise and at the head. The river discharge at the headworks and the likely natural flow below the storage dam are assessed and water admitted into the head canals. If further supplemetation is required, a call upon storage is made. Due note has to be taken of lags in discharge and time in deciding upon the require-

ments. The requirement is very variable from full discharge to nothing or almost nothing. The rain-fall over a large area, particularly in September and October cannot be uniform nor is the demand. Some areas may need some water and others none. The first task is to ensure the supply of the water under these varying conditions. It is not easy but with effort it has been possible to meet the problem, which will assume lesser proportions as the canal sections of the construction phase gradually assume their final form.

In the initial stages outlets have to be fitted in by trial. The problems of first irrigation are that while there may be too strong a flow at an outlet, that at another may be meagre. There may be too much water at one place and too little or none at another. There may be water-logging at one place and quick drainage elsewhere. According to the local conditions and in conjunction with the cultivators, the inequalities of flow are evened out by controlling and guiding the flow. Irrigation is field to field. Control and distribution are greatly assisted by their being divided into plots with the surrounding boundary ail bunds (ridges).

The irrigation requirement of water may go upto 12″ in a season—3″ during the ploughing and preparatory stages, 6″ during transplantation and 3″ during maturing. In years of good rainfall it would be less and may even come done to 3″.

In periods of drought the duty in July has been as low as 50 and as low as 74 in October due to the dry land soaking up the water. That has meant a longer rotation to cover the area but neither has transplantation suffered becuase of its allowable time-spannor maturing as the soil has never been allowed to be dried out. As a matter of fact though water is supplied to the whole area during ploughing and transplantation, those operations are much slower and lag behind. The supplies of labour, cattle, implements and seedlings are the ruling factors. Moreover they could not be increased so as to become economically redundant. That is a great help to irrigation at this stage as it affords the time for fully meeting the demand. In September and October the possibility of a drought is guarded against by always keeping water in the fields so that absolutely dry conditions cannot emerge and a critical stage cannot arise.

Just as irrigation has an influence, so has climate and its variations. Nevertheless the effect of irrigation is to tend to even out inequalities of yield. Normally the low level fields getting more rain water are better tended with more manure, better seed and greater care. The higher fields are cultivated but there is a sense of risk and the investment, on all counts, is less. With assured irrigation all lands would tend to be equalised. There would be more uniformity of cultivation, greater standardisation of paddy varieties and a uniformity in the yield. This would be a factor in increasing the overall yield above the level, expected from a consideration of the increase of the individual outturns.

Irrigation also helps in reducing the time required for the plants to take root and turn green again after the post-transplantation paleness.

The experience is that with irrigation the early autumn paddy is going out, the later variety becoming more wide-spread. Another effect appears to be that the greater moisture in the soil tends to retard flowering, maturing and the drying of the plant and consequently harvesting. The time fixity of Aman paddy is subjected to a degree of flexibility. Harvesting thus tends to be pushed further into December.

A few other effects noticed are:

(*i*) Irrigated paddy tends to have less tillering and and a smaller number of grains per ear than unirrigated paddy. But the weight of the grain is greater. It would appear to mean more mature grains with perhaps a greater protein content and a lighter husk. The proportion of chaff would be less. It would seem that it would stand milling better too with less breakage.

(*ii*) Significant increase in yield appears to come about from at least there waterings—one each during transplantation, growth and maturing.

The additional yield expected may go upto 14 maunds per acre, the average immediately standing at about 6 maunds per acre. Later on the average increase may go upto about 9 maunds per acre upon greater standardisation.

The requirement, however, both from economic and agricultural reasons is that it is necessary to introduce double-cropping in the single-crop Aman areas. Or alternatively it is necessary to have a value cash crop, such as sugarcane. For this the demand will create the supply. The imminent establishment of a Sugar Factory in the heart of the irrigation area will give the necessary fillip. For sugarcane the problem of irrigation is simpler. A light dose of water at sowing time in October-November and another perhaps in March-April for the summer will suffice for the November plantings. For the March-April sowing only a light dose at that time will be needed.

The difficulty however is for the second or rabi crop. The main problem is that the late aman paddy, which paradoxically enough is tending to get later, stands in its way and this is the main established popular crop. It will be necessary to induce its being exchanged in favour of the period fixed Aus paddy or even the time fixed Early Aman paddy to be followed by wheat, barley, potato, winter cotton, tobacco, groundnut, mustard, vegetables or a fodder crop such as berseem or lucerne. This would cover the time from November to March. The water rquirement would be from 9″ to 12″. In between a catch crop, preferably a soil-enriching legume, such as cowpea or kalai, can be taken or a green manure crop may be grown. The change over will have to be in large blocks for convenient irrigation in suitable areas with regard to soil and location. This development will grow in step with the retreat of the innate conservatism that is a marked feature in agriculture.

As the Kharif crop changes, the demand upon storage too will decrease, having more water for the extension of the rabi cropping. The increasing familiarity with irrigated farming also will result in a more economic use of irrigation water. Moreover double-cropping is a means to a fuller employment of the people.

As these developments come about a more rigid cycle of waterings—timely according to requirement and never too early—will be established.

The possibilities are great. The path has been opened and progress must result.

Problems and Possibilities of Irrigation Agriculture in West Bengal

By E. A. R. BANERJI

CROPS can be grown without soil, as in the hydroponic method or soil-less cultivation, but not without water. This is the principal medium through which all plants obtain their nourishment, and is indispensably necessary for growing all crops.

Water for raising agricultural crops generally comes from natural precipitation. Thus in regions where this is too little or ill distributed or uncertain, means of getting the requisite quantity of water from other sources to grow crops have to be thought about. An average well distributed annual precipitaion of 20" is considered to be the minimum requirement for intensive agriculture. Where this is less the region is classed as semi-arid or arid. Where the natural precipitation is higher than 20" irrigation is generally not required unless the rainfall is uneven as in many places in India and particularly in the State of West Bengal.

Irrigation agriculture, however, has its hazards, and if proper precautions are not taken the aftermath turns out to be disastrous. History bears ample testimony to this. Great civilisations have sprung up from time to time and were developed under irrigated agriculture but were soon destroyed since proper precautions were not taken. For instance, one of the earliest of the great civilisations which developed in the valleys of Euphrates and Tigris in Asia Minor had two of the largest irrigation systems. To-day Bagdad in the midst of these once productive irrigate plains, is now a barren desolate waste. Such examples are not lacking in India as well. The Indus Valley is an instance. Again, there are countries where irrigation water has been used from time immemorial without any bad consequence such as in China and in Egypt.

Scientific studies have shown that where irrigation agriculture has failed the main reason has been that the soil was not suitable for irrigation and the precautions that are required to be taken were not adopted.

In arid region the general experience is that heavy irrigation of the land results in bringing up of the water table and along with it saline and alkaline conditions. In recent time the Imperial Valley of California (U. S. A.) is an example. This has happened in the Punjab and Sind also. In heavy rainfall areas indiscriminate irrigation again can lead to marshy conditions by bringing up the water table. This lowers the productive potentialities of the land. Under water-logged condition only crops like low land rice can be grown. Whereas lands which are not water-logged can support a variety of crops, and as such, are considered to be agriculturally superior, and having much higher productive potentialities. If precautions are, therefore, not taken for proper drainage in heavy rainfall areas, in 10 to 15 years even lands which are fit for multiple cropping can easily become inferior lands and existing low lands which are only fit for growing rice can also become marshy wastes.

Under irrigation agriculture it is also necessary that the water that is available for productive purposes should be used as economically as possible. Every gallon of water that is either pumped or purchased is money wasted out of farmers' pocket if this water is wasted.

Agricultural Problem in West Bengal

The agricultural problem in West Bengal is that about 13 million acres of agricultural lands are required to support over 26 million human population and about 11 million cattle population. This can only be possible under a very intensive system of agriculture such as is in vogue in countries like China, Japan etc. Under such an intensive agriculture, not a single inch of land is allowed to remain fallow during any part of the year. In West Bengal the position is quite different at present. Out of 13 million acres of agricultural land, aman (transplanted winter rice) is grown on nearly 9 million acres and these 9 million acres are all low lands where water accumulates during the monsoon season for making possible the culture of this rice. Most of these lands, therefore, is under monoculture. The remaining 4 million acres are actually high lands where double or triple cropping is possible according to the availability of water. Unfortunately this is not always assured by any irrigation system and has to be obtained from improvised and local source such as tanks, wells, tubwells, etc. It is no wonder that the people of this State thus have to live on a bare subsistence level. The cattle in the State is also very poor. When it is hardly possible to meet the requirement of the human population naturally the cattle population has to starve. If the nutritional level is to be raised and the general prosperity of the State improved, the only solution, therefore, lies in the adoption of intensive form of agriculture.

Nature has bestowed upon this State a climatic condition under which crops can be raised all the year round. Only limiting factor, therefore, is the requirement of water. This, though seems paradoxical when the natural precipitation varies from 50″ to 150″ annually, nevertheless becomes a necessity since more than 90% of the to talprecipitation is obtained between the months of July aud September i. e. during the season agriculturally known as "kharif." The remaining 10% or even less is available only during the rest of the year. It is also ill distributed and uncertain, particularly for growing crops between the months of October to April i. e. during the season agriculturally known as "rabi." It is for this reason that introduction of irrigation agriculture has become a matter of paramount importance for raising the agricultural production and the economic level of the State.

Plans for Irrigation Agriculture in West Bengal

In order to raise the productive potentialities of the State various irrigation projects have already been undertaken and many more are visualised for the future. The biggest irrigation project is the Damodar Valley Project. This is nearing completion and is expected to supply irrigation water to about 1 million acres of land. Mayurakshi is another project and is also expected to supply water to 0.6 million acres of land. These together with other minor irrigation projects in the State in all are likely to irrigate about 2 million acres or little over. Again under the Second Five Year Plan another major irrigation project namely Kangsabati Project has been taken up. On its comletion another 0.8 million acres are expected to be added under irrigation. Thus not long before it can be visualised that nearly 3 million acres of land in West Bengal will get irrigation. This can considered no doubt a great achievement and should go a long way not only to solve the ever increasing food problem due to heavy population pressure but also to materially help in bringing greater prosperity to the country.

In addition to the areas which are to be commanded by the above irrigation projects, there are also areas in the State such as in the districts of Jalpaiguri and Cooch Behar in North Bengal where the water table is fairly high and it is possible to develop shallow tubewell irrigation. Innumerable such tubewells could easily be sunk at not a very heavy cost. In fact, in Madras the Agricultural Engineer has developed the construction of filter point tubewells which cost very little. If about Rs. 50 to Rs. 60 can beafforded, such small tubewells could be installed by the cultivator himself and he can irrigate from each tubewell 5 to 6 acres by bullock power. Again if electric power is available such tubewells with larger diameters could easily be installed in large numbers and worked in grids for irrigating vast areas. When West Bengal Goverment is going to generate hydel power under the Jaldhaka Project in North Bengal this electricity could perhaps be available in North Bengal for running shallow tubewells. The cost of irrigation by this means will also be not very heavy.

If irrigation agriculture is developed in North Bengal in the above manner and if small irrigation projects are also planned on the basis of water conservation principle it is not impossible to expect that at least 50% of the total agricultural areas in the State can be brought under irrigation agriculture.

Necessity of proper Utilisation of Irrigation Water

The prospect of adoption of irrigation agriculture as has been visualised no doubt indicates a bright future, but the most important necessity under irrigation agriculture is that the water should be utilised properly. It is, therefore, necessary to examine this question carefully. Atleast the manner in which the water is now being utilised where irrigation is water available, will give an indcation of it.

The method of irrigation that is practised at present by our cultivators seems to be far from satisfactory in this respect. The water that has been released from the major irrigation projects such as D.V.C. and the Mayurakshi is now being used for growing aman rice crop. That is for a crop which ordinarily should depend on natural precipitation. This is no doubt due to the necessity for ensuring the staple crop food against the hazards of uncertain weather condition, but the fact remains that the same water, instead of being used up completely for aman rice, if also used during rabi season, could have produced three crops from the land instead of one. This is, therefore, a matter of very serious consideration whether the present practice is at all a judicious one, especially when the irrigation water particularly from the major irrigation projects is being made available at a huge cost to the country. It is also a matter of serious consideration whether this practice is going to really solve the problem of incerased food production in the State at all. By growing aman rice with irrigation we cannot utilise the same land for another crop as it ties down the land from mid July to December, except when early aman rice is grown. In the latter case also the scope of growing a rabi crop under irrigation becomes rather remote as we use up all the water during the kharif season and there is no assurance of water supply during rabi season.

The irrigation practice that is now in vogue in the State of West Bengal thus does not fit in at all with its real aim that is to maximise production, and to raise the economic level of the country which is so wistfully visualised.

The irrigation water available from the major projects are also delivered to the rice fields by the flooding method. Although this may be all right for the cultivation of rice but in the flooding process the scattered pockets of high lands or medium high lands which are interspersed between the low lands which make up the major agricultural land in the State, also get submerged and water-logged. As such, high land crops which are cultivated on them simultaneously with rice in the low lands, also get submerged and do not get the ideal condition for proper growth and production. Thus the potentialities of these high lands which can support multiple cropping are also lowered by flood irrigation process. This manner of utilisation of irrigation water under heavy rainfall condition exposes the lands to the danger of getting eventually water-logged. This may not occur immediately, but there is likelihood of this happening in course of about 15 to 20 years depending on the permeability of the soil and the existence of natural drainage. If the latter is satisfactory the danger however may not arise at all. No detailed knowledge is however available of the nature of subsoils and its drainage conditions in the State. From the preponder-

ance of low lands one would naturally be led to conclude that the drainage condition is not at all satisfactory.

In the eagerness for increasing the production of the staple food that is aman rice by bringing more areas under this crop there has also been a tendency to destroy the natural drainage. Thus if the present outlook and the eagerness for producing more and more aman rice persists, and along with it if irrigation water is utilised it is not unlikely that before long more lands in the State would be converted into aman areas and the smaller proportion of high land which at present exists for multiple cropping may eventually disappear.

The system of irrigation which is practised at present, therefore, unqestionably does not hold out a bright future at ; all rather there is the likelihood that the productive potentialities of the State will further deteriorate under this system of irrigation agriculture and eventually we will be producing only aman rice and nothing else.

Need for Conservation Irrigation

Conservation irrigation is a relatively new term although in basic conception it means simply the use of irrigated soil and irrigation water in a way which will ensure high production without waste of either water or soil. From what has been stated earlier it would be evident that our present conception of irrigation agriculture in the State is far from what conservation irrigation means. Although our aim is only to temporarily ensure the main rice crop, at the same time our lands are being endangered to the hazards of ultimate deterioration which will eventually frustrate the very objective of spending so much money for supply of irrigation water. The irrigation facilities which have been created in the State or will be created in future thus can only bestow its lasting benefit if conservation system of irrigation practice is adopted.

For this first a complete change in the outlook of growing crops under irrigated condition is required. It is a general belief that the habit of growing aman rice is very old and hard for the people to give up. Besides this supplies the staple food with which the people of the State have become adjusted from time immemorial and it would be difficult to expect them to give this up. This is no doubt true, but in suggesting the change in the cropping it is however not at all intended that the people should give up growing and eating rice. The varieties of aman rice that are grown in West Bengal belong to the physiological group known as "timely fixed". That is whenever they are sown and transplanted they will always come to flower by the middle or third week of October and will mature from November to December. There is another physiological group of rice known as "period fixed", the behaviour of which is different. They are actually our aus variety, which are grown generally on high lands and can also be grown under transplanted condition on medium high lands as is being done in some of the districts e.g. Bankura, Birbhum etc. These varieties have fixed life periods from 60 to 120 days or even more. These varieties are however somewhat disfavoured by our cultivators as they are generally coarse and on cooking become sticky. For these reasons this variety is grown only as a subsidiary rice crop and is consumed only by the poorer class for their sustenance until the main crop is available. To change the quality of aus is not at all difficult as is well known to plant breeders. In fact, this has been done in countries where now rice is being grown under irrigation. For the irrigated areas of West Bengal also if varieties of rice are evolved having the habits of aus and the quality of aman, it can easily solve the problem of being able to stick to rice eating habit and at the same time permitting a more judicious and economical use of irrigation water. If such varieties are introduced in irrigated areas they could either be grown as broadcast rice or may be line sown or they can even be transplanted according to type of land available. Such varieties of rice could be harvested early for growing another crop with the irrigation water that is at present supplied. Since the water requirement of this variety will be very much less than that of aman variety it will also be possible to conserve irrigation water during kharif season by depending as far as possible on natural precipitation, and utilise the irrigation water more for growing crops during rabi season. In this way the water that we now use up for growing only aman rice can be utilised for growing three crops, and all the year round, and the irrigation can be of perennial nature. The most suitable rotations under perennial irrigation may be as follows :—

1. Aus	Pulse	Wheat	or	Jute.
2. Jute	Aus	Pulse		
3. Jute	Aus	Oilseed		
etc.	etc.			

Under such a rotation system the fertility of land can also be ensured and it will be possible to have multiplicity of crops for self-sufficiency of the State. It will also allow scope for growing short duration fodder crops like joar, fodder legumes etc. as catch crops in between the main crops.

The change of cropping pattern as suggested above can again be made more successful if proper drainage system is developed in the country. If the aman lands which get submerged during monsoon could be drained out, the potentialities of these lands would also became greater for adopting multiple cropping on all lands. This will also guard against the danger of water table coming up and making the land water logged. The necessity of proper drainage along with irrigation is thus considered very important wherever irrigation agriculture is practised and great emphasis is now being given to this, due to the technical knowledge that has been gained so far regarding irrigation-agriculture.

Planning for Conservation Irrigation

In the context of what has been stated it would be clear that to implement the suggestion for proper utilisation of water the change in the outlook of the cultivators is of paramount importance. Along with this it is also necessary to evolve and introduce suitable varieties of rice which would have the quality of aman but growth habit of aus. It is also necessary to provide perennial irrigation by curtailing supply, of water during kharif and proper drainage of excess water during monsoon. The latter could again p ssibly be stored up at convenient places for utilisation during dry season.

In areas where irrigatic n has been provided there also does not exist proper distributary system from

the main channel for supplying water to different fields according to their needs. This distribution of water to different fields is regarded as the responsibility of the cultivator himself but to plan this is quite difficult and requires good deal of technical knowledge and data concerning contour of the lands, natural drainage etc. The planning of proper distributary system is not possible for cultivators to do themselves. Besides when individual holdings are small this planning has to be done on block basis, to meet the requirement of all in the block and for proper supply of water to each and every field according to the requirement of different crops. Even in advanced countries like U.S.A. and Europe such planning is done by appropriate technicians.

The vital necessity for such planning of proper distributary system has been completely overlooked so far in West Bengal where irrigation water has already been provided. Unless this is done irrigation water can never be utilised economically. If the water is wasted the cultivators will also not be able to understand its proper value and pay the price for it accordingly. It is for this reason that although good deal of money has been spent in this State for providing irrigation this has not been fully appreciated by the users. When its proper and economical use is shown to them then only they will understand what great benefit irrigation is going to bring to individual cultivators and to the country in general. They will also not hesitate to pay the price for water as well, about which there is good deal of reluctance on their part at present.

Conclusion

What has been stated here is only a brief analysis of the problems and possibilities of irrigation agriculture in the State of West Bengal. The main object of this article is, however, to focus attention of the Government, the politicians of the State, the technical persons who are concerned with the development of irrigation agriculture, and lastly the farmers and cultivators of this country, in order to bring about a consciousness of what we are actually doing and what we actually should do in connection with the introduction of irrigation agriculture in the State, in order to aim at fuller and better life and freedom from want which is the ultimate goal of political freedom which we have achieved.

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Problems of Possibilities of Irrigation in West Bengal

There are other ways of utilising such low lands for growing more food.

(*a*) converting the area into a fishery. With the industrial area of greater Calcutta so near there will be no dearth of market for fish produce even if fisheries are developed on an extensive scale.

(*b*) Adoption of floating cultivation.

This is done in the lakes in Kashmir and it may be a success here as well, provided concentration of salts is guarded against (this may be done by flushing with fresh water once or twice a year and draining as far as practicable. Usually vegetables are grown in Kashmir on such floating "lands" and Calcutta has a good vegetable market also.

The Sundarbans area has a vast potential if proper planning is made before the prospects are ruined. A slow programme should be adopted for this area to keep as much land as possible under the influence of floods as long as possible. This prospect of development should be left for the future generation but proper planning may be made ahead now. The proposals are :

(*a*) Closing the estuary wholly (except the Hooghly) and draining through sluices,

(*b*) Closing the estuary leaving the major drainage channels,

(*c*) Strengthening the Zemindars' embankments, converting each bit of land into a drainage basin.

The first one will be rather costly and be beyond the country's means to think of. The second proposal requires test on models to show how the estuarine rivers will behave when confronted with sluices. Pumping may ultimately have to be adopted as a time may come when the sluice channels will deteriorate and be ineffective. The third proposal is bound to choke the existing drainage channels sooner and in due course the whole area will have to be brought under pumping.

Northern Zone

This zone covers the areas in Darjeeling, Jalpaiguri, West Dinajpur and Cooch Behar districts. In most of these areas the monsoon rainfall is rather high and there is not much demand for irrigation in kharif season. But with irrigation a second staple crop may be grown in a substantial portion of the area. The terai area is well known for rice cultivation. For irrigation there will never be any dearth of water as there are a number of snow fed rivers passing through this area. Darjeeling and Dooars areas are well suited for tea plantation as the lands lying on the slopes are well drained as also there is plenty of rainfall so essential for tea growing.

Central Zone

The Central Zone consists of districts of Maldah, Murshidabad and Nadia. The land being comparatively flat the drainage is not so quick and these areas can overcome effects of droughts, and hence there is not much demand for irrigation here. However, a timely irrigation in October is felt necessary occasionally. Besides, there is great possibility of growing sugarcane and rabi crops like wheat (after an early paddy crop) if irrigation is made available. There are two ways of irrigating these lands :

(1) By drawing from the proposed Ganga Barrage. The requirement will not be much and for short periods only.

(2) By sinking wells and tube wells and using electric pumps.

This area was once very fertile but with the decadence of rivers in the area much of the lands have lost their fertility. This fertility of such lands may be revived by occasional flushing with the fresh river water, say, from the Ganga Barrage. Such flushing will not only remove the excess accumulation of salt in the area but will improve condition by bringing in fine river silt to the country.

Effect of Irrigation upon the Soils of Damodar Canal commanded areas of Burdwan

By S. K. MUKERJI

Irrigation of the alluvial tracts of the district of Burdwan could have been planned either through a system of tubewells or by canals. The tubewells would have consumed energy generated from the hydro-electric or thermal power station situated in the Chotanagpur plateau and the canals could be fed from the surplus water from the dams by barrage and distributaries. In these two separate methods of irrigation we are dealing with irrigation water which differ in quality. The following gives an average of fortnightly observations taken for one year in the commanded area. The composition of water of the river Nile has also been shown for purpose of comparison.

	pH	E.C. $\times 10^6$	Ca	Mg	Na	K
			(mill equivalents per litre)			
Eden Canal	7.2	350	0.792	0.65	1.20	0.084
Deep tubewell	7.0	450	1.69	0.61	1.23	0.21
Nile water, flood to low	(1,2)	173	0.64 to 0.87	0.57 to 0.72	0.56 to 2.04	

Water from both these sources are salt free and are admirably suited for irrigation. But irrigation is a two-edged thing ; it is a good thing to irrigate with tubewell waters containing nutritive substances like Calcium and Potassium and not nearly so convenient to irrigate with less nutritious canal water which may leach the soil under irrigation. These soils are partially unsaturated and slightly acidic and have a low reserve of Calcium unlike that of Egypt where soils are mildly alkaline and have a reserve of 4-8 percent calcium carbonate and therefore the composition of water indicates that the canal water could not get much preference over the system of irrigation by tubewells.

Diverse effects are also produced on the level of subsoil water. In the case of tubewell irrigation, the level of subsoil water may be lowered causing the numerous tanks in this district to dry up and the wells as well, adding misery to the farmers. The surface irrigation, on the other hand, may raise the level of subsoil water and may thus ruin the more valuable paddy growing areas which are at present located in the lower topography.

Economically, however, the development of surface irrigation for agriculture and navigation and sparing the whole electric power for industry and transport seem to be more sound.

Surface irrigation has its shortcomings. The degree of damage and nature of preventive measures depend upon the nature of soils which are irrigated. The soils of the commended areas of the D.V.C. have been studied and classified on the basis of genesis, topography, mode of formation, the design and developments of the profiles and geography by the directorate of Agriculture, West Bengal.

The different kinds of soils to be irrigated are !

(1) Lateritic
(2) Red soils
(3) Damodar Uplands
(4) Damodar flat lands
(5) Damodar Riverine lands
(6) Ganga Flat lands
(7) Ganga Riverine
(8) Damodar Flat lands over buried laterite

These different groups or associations of soils will naturally behave differently under irrigation due to their morphology and the nature of soils in different layers as are indicated by their physico-chemical properties. The following gives in brief most probable reactions of these soils under irrigation.

Laterites

These soils need irrigation most, but due to the fact that these soils have been excluded from the area commanded by the Damodar Canal system, their behaviour under irrigation has not been discussed.

Red Soils

Next to the laterites the requirement of irrigation water for red soil is the most urgent. These are leached soils, having a zone of accumulation of clay with pisolitic small concretions below. Salinity was examined up to the depth of water table at many places during the period of survey by digging test pits. The salt concentrations were low in the top, and increased very slightly with depth, but in none of the soil layers examined high salinity could be met with or any layer of sodium soil could be detected. The salt content varied from 0.02 to 0.06 percent. The clayey layers looked permeable.

The texture of the soils on the surface in a majority of the area is loam to sandy-loam and in depressions clay or clay-loams. These are underlain by a heavier layer of soil. At a depth of 4-6 feet the soil layer was found to be heaviest and had iron-manganese concretions indicating that, this soil zone gets water-logged during rains. Lateral movement of gravitational water takes places easily in these soils. Numerous small rivulets flowing through the red soil area drain the gravitational water away and thus on the whole maintain a good aerable condition. Below this layer of clay, the subsoil is either gravelly or consist of whitish decomposed rock, or of coarse sand. Therefore, there is, very little likelihood of any chance of water-logging and formation of swamps.

But there is a certain amount of hazard of scouring of surface soil by the velocity of flood irrigation. If the area to be irrigated is from a small cut, the scouring due to the velocity of the water may be low. But, when big areas are to be flooded by a single puncture in the canal banks, the volume of the water that moves may scour the fields. This hazard may be attended properly to prevent damage to the soils situated on higher terraces.

The above holds good for such association, where this group of soil forms as one of the components.

Damodar Uplands

This constitute an extensive area being commanded by the Damodar Canal System. The morphology, the physico-chemical properties of the soil and their situation show that the problem of salinity, quick rising of water table and formation of swamps may not be serious with this association of soils. The volume of discharge from a cut in the canal is usually very large and scour the soil. The soil is mildly acidic and is partially unsaturated and therefore has a tendency to move with the current of water. This movement of surface soil from the cultivated fields may result in loss of fertility, especially in the upper reaches of the cut. Loss of fertility may thus take place by quick running of great volumes of water during flooding an area. Therefore this may constitute a problem for engineers, who may make suitable designs to make the irrigation water move slowly.

Numerous test pits were examined to a depth of 18-20 feet in this area. The soils in the profiles did not indicate any layer having a high concentration of soluble salts or the presence of a sodium soil. The soil to a depth is clayey interspersed with dolomite. Down below this layer of clay (10 ft.- 40 ft.) lighter subsoil consisting of coarse sand or gravelly sand exist. The clay is a calcium one having over 80 percent calcium saturation in the exchange complex. This clay layer has therefore a slow to very slow permeability. But due to the terrain, which rolls from West to East, step by step, the water which soaks through has a tendency to move between the soil layers and emerge out in numerous openings which app ar in the landscape as minor rivulets and thus the area gets drained. In the rains, the supply of water by precipitation exceed the rate of downward movement of water due to infiltration and therefore the area appears to be under water-logged conditions.

But as soon as the rains stop for a fortnight or so, the water in the paddy fieds percolate through and the area becomes free from surface water standing on it, except in low depressions.

It is evident, therefore, that even though considerable movement of water to the lower layers, due to permeability of the soil takes place the chances of water logging or swamp fromation or rising of water table is remote so long as the numerous minor rivulets, which drain the subsoil are not plugged. This process also helps in the removal of salts and thus the chances of developmet of salinity is remote indeed. The irrigational problems of this area, therefore, appear to be one of making the irrigation water to move slowly, so that scouring of surface soil and consequent leaching away of the nutrients are reduced to a minimum.

Damodar Flat Lands

This constitutes the largest area commanded by the Damodar-Mayurakshi Canal System and enjoys the privileged position of sustaining increased production by the help of irrigation water. A number of deep test pits were examined all over the area. Different layers of soil indicate (1) the absence of layer of sodium soil (2) the presence of subsoils having calcium in the exchange complex (3) that the surface soil is leached and is very mildly acidic and subsoils neutral in reaction (4) that all the layers are moderately permeable and (5) the absence of layers rich in soluble salts.

Further leaching may reduce the low calcium status of the soils resulting in greater unsaturation which may in the long run reduce productivity.

The area has a good subsoil drainage and therefore there is not much likelihood of formation of swamps except in a few low lying pockets.

The above two factors, however, can easily be controlled if proper care is taken. Productivity of these soils can be maintained at a high level almost indefinitely.

Damodar Riverine Lands

A number of deep test pits all over the area indicate that these soils are quite permeable and have lighter

subsoils up to the water table. Below this the subsoils can be divided into two classes having:

(1) Coarse sand and

(2) Thick, black clay.

Evidently the area having coarse sand in deep sub-sub-stratum do not as a rule constitute a very serious problem. But the second category where the subsoil is a deep black clay having 10-15 percent saturation with sodium constitute the danger zone. Fortunately this layer is below the water table, yet this layer of sodium soil may be a factor which may be worth taking care of.

Profiles up to 6 ft. reveal the presence of one or more sandy layers. These sandy layers occur at different depths from the surface. Irrigation water may find their way into subsoils through these sandy layers which have low water holding capacity. This water moving into the subsoils due to gravity through these easily permeable layers may raise the water table. The profiles examined upto the present water table indicate that these are very low in soluble salts and there may not be many cases of damage due to salt efflorescence.

The area occupied by the riverine tract occurs at a low topographic level. The subsoil water remains near the surface within 6 to 8 ft. even in summer. If the subsoil water rises further as a result of irrigation, growing of any other crop besides paddy may not be possible. Health conditions, which are already poor, may worsen. The soils, otherwise, are good aerable ones and can support a variety of economical crop. A close check of the rise of water table and controlling the irrigations accordingly may be essential. The control of rise of subsoil water in the area having sodium clay in the deep subsoil may be an immediate necessity.

The nature of this subsoil can best be realised if the exchangeables, pH and salt contents of each layer of the soil is studied up to a depth of 44 feet in this area. A profile to a depth of 44 ft. was dug in a site between Palla road and Masagram near the junction where the navigation canal crosses the New Chord Railway line. This site is situated in the Damodar Riverine soil tract and is expected to carry a large load of irrigation water in future and is typical of the tract having a subsoil of saline black clay. The following is the chemical composition:

Salinity, pH and Exchangeable in a typical deep profile

Deep in feet	*pH*	*Water Soluble Salts percent*	*Exchangeable S mili equivalents percent*				
			H	*Ca*	*Mg*	*K*	*Na*
0-2	5.5	0.108	9.3	4.62	4.4	0.19	1.37
2-4	5.9	0.041	7.5	5.42	2.93	0.11	1.27
4-6	6.1	0.032	2.3	6.77	5.57	0.19	1.85
6-8	6.2	0.020	—	10.01	5.14	0.21	2.14
8-10	6.2	0.028	1.4	8.89	6.14	0.19	1.85
10-12	7.0	0.025	—	7.08	13.05	0.24	2.25
12-14	6.8	0.380	0.5	7.7	16.68	0.26	2.86
14-16	7.1	0.400	—	8.0	15.68	0.26	4.03
16-18	7.4	0.440	—	17.0	15.55	0.37	3.60
18-20	7.3	0.340	—	15.9	12.98	0.35	3.97
20-24	7.3	0.316	—	9.8	10.90	0.29	2.79
24-28	7.0	0.362	—	12.6	12.8	0.35	3.70
28-32	7.1	0.362	—	14.9	16.7	0.35	3.87
36-40	7.0	0.41	—	18.3	14.7	0.43	3.95
40-44	7.2	0.40	—	20.3	12.3	0.40	3.70

These soils become saline at a depth below 12 ft. and the salinity continues to increase slowly up to the last layer of soil examined. At 10 ft. the soil changes from a calcium to a magnesium soil and remains so till a depth of 36 ft. is reached beyond which it is once again a calcium soil. The top soils are unsaturated, evidently due to the leaching by rain water. The following reveals the texture and the nature ofthe clay.

Depth in ft.	*Unsaturation percent*	*E.S.P.*	*Silt*	*Clay*	*Sand*
0-2	47	6.91	2.35	17.64	80.11
2-4	43	7.35	4.20	14.01	81.79
4-6	14	9.31	19.20	22.30	58.50
6-8	—	12.22	15.25	42.37	42.38
8-10	7	10.00	3.64	36.36	60.00
10-12	—	9.95	22.17	21.22	56.11
12-14	1.8	12.36	3.57	53.57	43.86
14-16	—	14.39	9.09	22.72	68.19
16-18	—	9.86	23.90	57.07	19.03
18-20	—	11.94	18.05	39.39	42.56
20-24	—	11.72	7.62	19.04	73.34
24-28	—	10.62	8.57	37.85	53.58
28-32	—	10.34	17.84	40.94	41.22
32-36	—	9.81	27.91	56.81	15.28
36-40	—	10.57	22.33	54.12	23.55
40-44	—	10.08	14.40	48.60	37.00

The exchangeable sodium percentage in the whole profile is below 15 percent indicating that we have a purely saline subsoil below. The percentage of sodium is always greater than that of potassium. The texture tends to be heavier with depth, though in between them have occasional light layers. It may be noted that in none of these light layers the clay percentage is less than 10 percent. But since the top soil is a hydrogen over calcium soil, the permeability is high and loss by seepage may not be very small. The seepage and the saline subsoil are the two disadvantages of the soil series.

There are numerous rivulets but the custom of blocking them, to obtain irrigation water has been responsible for raising their beds. They, therefore, can hardly suffice to carry the vast volume of seepage water for perrenial irrigation. The irrigation of the uplands and flatlands may also add to volume of subsoil water. The remedy may apparently lie in the bunding of rivulets in the riverine tract to obtain water and re-excavation of the beds wherever these have been permanently blocked. Prohibition of cultivating the beds of the rivers and creation of new arteries to carry off excess subsoil water wherever it is found imperative, may also prove beneficial.

Ganga Flat Lands

In the area occupied by the Soil Association of Ganga flatlands, the water tables vary from 4 to 6 ft. in summer to surface during rains. Examination of soils from test pits indicate that in none of the layers salt exceeds 0.07 percent and layer or layers of clay having sodium in the exchange complex is absent. Topographically, this area lies mostly between 28 to 48 ft. above sea level.

These lands have some disadvantages under irrigation. The landscape is interspersed by abandoned river beds, many of which still go under water during rains. Cultivation is limited to the periphery extending almost to the deepest part and crops like the *aman* and *baora* paddy can grow. Most of the valuable paddy lands are situated around and in these depressions. It is therefore not very difficult to visualise as to the effect of an uprise of the present water table as a result of irrigation.

The locality, occupied by these soils have had already a notoriety for malaria. Formation of swamps and marshes as a result of depressions getting submerged will aggravate unhealthy conditions. There is no threat either from soil being lost or from salt efflore-

[*Continued on page* 88

Subject IV

Possibilities & Prospects of Power in West Bengal— Both Thermal & Hydro

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Future Trend of Power Development in West Bengal

By A. K. BHOWMICK

IN the modern world of today a country's position is judged by its industrial development and electrical power and the latter is the foundation of all industrial growth. And again the standard of living of the people is judged by various factors of which per capita consumption of electricity is a very important one. At the end of the First Five Year Plan the per capita consumption of electricity has been raised from 14 units in 1950-51 to 25 units in 1955-56. This figure is expected to be increased to 50 at the end of Second Five Year Plan.

The planning for power must be based on long-term objectives. When the First Plan was prepared it was decided to add 7 million kW in 15 years. But the rate of growth of industries has surpassed all expectations and it is now expected that this additional target of 7 million kW will have to be achieved much earlier than anticipated five years ago. In assessing future demand for power it will be extremely erroneous if we base our estimates on the rate of past developments of industry & urban and semi-urban areas.

The total installed capacity of power plant in the country will be increased from 3.4 million kW to 6.8 million kW in 1961. Out of 3.4 million kW of power, 2.9 million kW will be installed under the public sector of the plant and it will comprise of 2.1 million kW of hydro electric plant and 800,000 kW of thermal plant.

A very rough preliminary study indicates that 35 million kW of potential power can be developed by utilising the various river resources in the country. More thorough investigation and survey will be carried out during the Second Plan Period so that the report is fully complete and big hydro electric projects can be undertaken during the third plan.

Hydro Generation in West Bengal

The total installed capacity of the hydro generating sets in West Bengal at the beginning of the First Plan period was only 3 MW with generation at Darjeeling and Kurseong. During the 1st Five Year Plan period Mayurakshi Hydro-electric Project was undertaken at a cost of Rs. 63 lakhs. The installed capacity of the hydro station is 4000 kW of which 2000 kW will be available throughout the year and an additional 2000 kW for the monsoon period only.

The scheme is now complete and the sets are in operation. The 33 kV double circuit line has been drawn between Massenjore Power Station and Pandaveswar, where the Board is also purchasing power from D. V. C. for electrification of the surrounding coalfield areas.

The other hydro-electric project which has been undertaken by the State is the one by utilising the Jaldhaka river in the border of India and Bhutan. The installed generating capacity will be 24,000 kW with two sets each of 12,000 kW. A firm power of 12,000 kW will be available throughout the year and an additional 12,000 kW will be available for 8 months during the monsoon period. Investigation work is complete and the civil works have already been undertaken and the project is expected to be completed by the end of the 2nd Plan period.

The 3rd hydro-electric project in the State will be materialised when the Balasun Scheme is undertaken. Preliminary investigation work in connection with utilising this river power is being carried out and when the first phase of the scheme is complete, 2500 kW of power will be available throughout the year and an additional 2,500 kW for 8 months during the monsoon period.

Thus at the end of the Second Plan generation of electrical power by utilising river resources will be 36 MW only. But there is every possibility of developing power by utilising the river Teesta in Darjeeling district. A development wing has been created for carrying out detailed survey and investigation to assess the power potential of the river. From the preliminary data available from topographical maps and records it seems that 300-400 MW of power could be generated by utilising an available head of 300-350 ft. and a discharge of 15,000 cusecs. It is expected that all investigation work will be completed during the Second Plan period so that work can be taken in hand under the 3rd Plan.

Apart from the fact that there will be a large demand for power by the Tea-Estates of North

Bengal and other associated industries, a large block of power has to be transmitted to Calcutta by a 275 kV transmission line to meet the growing demand of the city and surrounding areas. The power demand of tea-estates and other industries is expected to aggregate to 50 MW at the end of 3rd Plan.

The present demand of the Calcutta Electric Supply Corporation is 300 MW which will go upto about 450 MW by 1960-61. Out of this additional demand of 150 MW, 50 MW will be met from the Calcutta Electric Supply's existing sources and 100 MW from D. V. C. The rate of growth per year is expected to be in the order of 30-40 MW. So by the end of the 3rd Plan period the Calcutta Electric Supply would require another 150 MW and by the end of the 4th Plan, i. e. by the end of 1970, another 150-300 MW. Or, in other words, to meet the growing demand of the Calcutta area itself from 1960 onwards, a provision of of power in the neighbourhood of 400-500 MW has to to be made.

An extra high voltage grid will be absolutely necessary for inter-connection of generating stations within each area for the pooling of spare plant and consideration of generation at the more-economical stations. This also permits useful economics to be made by off-peak transmission of energy from the most economical stations in some areas to other areas where generation costs are higher. These are some of the main considerations which prompted British Electricity Authority to change their main transmission voltage from 132 kV to 275 kV. It was found after thoughtful assessment of various factors involved that for a division of the country like England into two halves, North and South, each with a maximum demand of 5000 MW, interconnection capacity of 390 MW between the two parts will be required. In fact there were only two circuits between North and the South of England, giving a safe transfer of 90 MW only. On numerous occasions this has been insufficient to avoid load shedding in one half of the country when surplus generating capacity is available in the other.

The same situation may arise in case of West Bengal too. With the concentration of all the industries in Calcutta and on the two banks of river Hooghly, shortage of power in Calcutta and adjoining areas is bound to occur while sufficient hydro power may be available in North Bengal. In such circumstances, erection of double circuit 275 kV line from North Bengal feeding Calcutta will be a most reasonable proposition. Investigation in U.K. and in other countries shows that the cost of extra higher voltage system meeting the minimum requirements would be no more and probably less than that of an equivalent lesser voltage superimposed system. In our case it is further more important to consider the fact that the function of our Grid is inter-connection as well as long distance transmission. Thus higher voltage will be more economical and as investigation work progresses it may be worthwhile to consider whether the line should be insulated for 380 kV as has been done in Sweden.

Thermal Generation

The present installed capacity of thermal generating sets in the State is 540 MW. During the 2nd Plan period this figure will be increased to 750 MW by installing 2 - 75 MW by D. V. C. and 2-30,000 kW sets by the West Bengal Government. Both the generating stations will be located at Durgapur—one close to the Coke Oven Plant and another close to the Steel Plant. Both these plants will require extensions as soon as they are completed by 1959 to meet the heavy indusrial demand in the area concerned.

It is also envisaged that a 132 kV transmission line will be erected between Durgapur and Beldanga in Murshidabad district and thus interconnection with the existing North Calcutta systems which will cater for the demand of power for execution of tube-well irrigation schemes requiring power of 10 MW by the end of 2nd Plan. Another 132 kV double circuit line may have to be erected between Calcutta and Durgapur for meeting the shortage of power in Calcutta and adjoining areas in the beginning of the 3rd Plan period.

Both big and small industries will grow and will grow beyond expectation and it will have a disastrous effect on the entire economy of the country if the industrial growth is checked in future for shortage of power. Moreover, the per capita consumption of energy is a rough measure of the standard of living of a people. As the economic level of our people is raised, a huge demand for power is expected to grow.

Lastly we may have to plan for bulding up of atomic power reactors in the country and it is expected that by the end of the 3rd Plan, bulding up of an Atomic Power Station of 100 MW or more capacity may be possible in West Bengal.

We have in India enough Uranium Ore from which 15000 tons of the metal can be extracted. This figure is obtained from a preliminary survey and there is every hope that future search will prove that much more quantity will be available than mentioned. We have also a storage of 180,000 tons of Thorium in a readily extractable form.

It is well known that U_{235} occurs in $Uranium_{238}$ to the extent of ·7%. This is a fissile material. One ton of U_{235} produces the same heat energy as that produced by 3 million tons of coal. Plutonium or U_{233} is the fuel used in atomic reactors. Such a Reactor having a capacity of 92 MW is in operation in Calder Hall, U. K. Over 1000 tons of extra-pure graphite is loaded into each reactor from the dome of which 250 tons of Uranium fuel is inserted. Once the reactors are running they will be in service for long period. The cost of generation by Atomic Reactors will compare favourably if power is produced in bulk quantity.

The working of atomic plants will need highly skilled personnel. Starting from the mining of crude Uranium Oxide which is present only as 100 parts in a million of the ore, to the final machining and assembly of the aluminium encased slugs in a graphite moderated pile where all impurities must be removed and then plutonium is extracted from the slugs. All this involves creation of new precision atomic industry and high engineering skill will be needed for assembling an atomic plant.

Planning for power on a national basis has been undertaken by Central Water and Power Commission and in the future years to come India will need a large-

number of expert engineers, technicians skilled and semi-skilled workers for bringing about a technological revolution in the country and the execution of all the plans will depend on the output of engineers and technicians which our technical institutions will be able to produce.

DISCUSSION

R. N. GANGULI:

Question 1.

From a reference to the white paper presented in the British Parliament, reports on Geneva, Mr. V. A. Pask's paper in the proceedings of I.E.E. and different publications of C.W. & P.C. we find that the costs of nuclear Power Stations built in U. S. A., U. K. or Canada are as high as 250 to 300% of a conventional thermal Power Station.

Great Britain is forced to develop her atomic power as a serious shortage of coal and oil is anticipated there. Her hydro resources are limited.

The problem in India, particularly in Bengal, is somewhat different. We have a huge reserves of inferior coal. (Total Indian reserves is 39,000 million tons which will last for many decades). Minehead Thermal Power Station will not only generate power cheaply but will also save millions of rupees in foreign exchange. Our hydro resources were neither fully developed nor critically estimated.

Would it therefore be justifiable at the present juncture to build an atomic power station of 100 M.W. capacity when atomic power station design has not even achieved a fairly stable technological perfection ?

Or should we wait and carry on research work in the atomic field and delay the construction of atomic power stations till more economic methods are found ?

Question 2

If an atomic power station comes into operation, we have to operate it at highest possible load factor at or about 100 % load factor. The total installed capacity of power plants in West Bengal does not exceed 500 MW.

Unless we have grandiose grid interconnecting all power stations with the facilities of proper protective and metering devices for quick transfer of load from one power station to the other, would it be a practical proposition to run the power station as a Base Load Station ?

Question 3.

Our demand for next ten years will be heavy. For first few critical years of commissioning nuclear plant it is necessary to have sufficient spare plants as reserve for operation in emergency to cover nuclear outages.

Would it be possible to have spare power plants in West Bengal where the rate of growth of demand almost exceeds the rate of growth of generation ?

There is no doubt that atomic power station will be put in hand before long but I feel that in view of abundant supply of coal in the Ranigunj areas it would appear that nuclear generation is not at the moment likely to replace conventional methods of generation i.e. coal burning stations with high steam pressure and temperature conditions.

P. R. ROY CHOUDHURY:

Major countries like U.S.A., Great Britain and U.S.S.R. have now started building Atomic Power Stations although the same are still in experimental stage. U.S.A. and U.S.S.R. have started this work although their needs are not as great as that of Great Britain, because they want to gain experience before they could take up the same on large scale. These countries are in position to fall back on conventional sources of energy like coal and water. With the limitation in hydro potential and coal resources, Great Britain is probably concentrating on the development of Atomic Power Stations on a large scale with all earnestness.

U.S.S.R. has planned to build 2.5 million kW of nuclear plants by 1960 comprising of 8 plants with capacity ranging between 300 to 600 MW at a cost which is not even twice now as compared with the conventional generating unit, in areas where coal and hydro potential do not exist. The Government is willing to subsidize this programme. The U.S.A. has also published proposals for installation of 75 MW. Total amount under consideration is not yet available.

The cost of the Atomic Power Station of the CEA in Great Britain is said to be approximately £150 per kW installed as against £64 (approx.) of the conventional generating units. The cost seems to be prohibitive and uneconomical for commercial purposes as compared with the other sources of energy.

Sri Gulzarilal Nanda, Minister for Irrigation & Power, while addressing the recent Power Engineers' conference in January, 1957 at Bangalore announced that the Atomic Energy Department is contemplating to build a 140 MW Atomic Power Station as an experimental measure. It may be presumed that the station although an experimental one will be used to the best advantage for commercial power supply.

Atomic Power Station requires base load preferably upto its full capacity even for the experiment. It can only be viewed as an integral part of a Grid and it may not operate as an independent unit. The system with which the power station will be interconnected must be capable of providing a base load of about 100 MW. The station perhaps will need a sparsely populated to site with facility for disposal of radio-active residues.

Coastal areas of West Bengal might offer one of the most suitable locations for this experimental station on the following considerations :

(*i*) the areas are sparsely populated ;

(*ii*) the D.V.C. and CESC Power Systems with which the station may be interconnected will have a base load considerably higher than 100 MW ;

(*iii*) it will augment the power supply position in the highly industrialized areas like Calcutta and DVC, which is likely to experience power shortage in the near future.

(*iv*) it has been reported that there are deposits of Uranium in Purulia region.

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Effect of Irrigation upon the Soils of Damodar Canal commanded areas of Burdwan

scence, but from the rising of water table, submerging valuable paddy areas. Watch on the rise of subsoil water and controlling irrigation accordingly suggest themselves so that this harmful effect may be deferred.

Ganga Riverine

This association of soils has highly permeable subsoil. This is due both to the presence of calcium carbonate and to the finer sands being predominant in the lower depths of the profiles. The Bhagirathi and its tributaries are affording the best means of underground drainage. Soil examined by deep test pits indicate high salinity in lower layers. But as the tendency of the salts is to go down the profile, therefore not much trouble is expected from salinity unless considerable rise of subsoil water occurs due to artificially choking up of the numerous small channels. Cultivation of the riverbeds is to be avoided.

Summary

Suitability of irrigation of different categories of soils found in Burdwan have been discussed.

The Ganga flat lands and Damodar Riverine series have been found to be liable to damages under certain conditions. These conditions have been discussed.

Acknowledgement

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Ministry of Agriculture Egypt Bulletin No. 250, 1949.

DISCUSSION

Dr. R. C. HOON:

It is being increasingly realized that the irrigation comprises not only distribution of water, but water laden with silt. The object of my remarks in that connection was to direct the attention of one of the authors of the papers and others present at the meeting to the fertilizing aspect which is generally attributed to the river silt.

Rightly or wrongly, certain fertilizing values are attributed to the river silt. The public in general and our cultivators in particular have got so used ot the conception of the land being flooded with silt-laden water that when they find that certain measures are being taken by engineers to stop flooding of their land by river water, they oppose such measures. Some thought has to be bestowed to this question of the fertilizing aspect of river silt. Has the river silt really got any fertilizing characteristics ? Or is it due to the mechanical and textural improvement which the addition of silt has on the cultivable land ? Or is it the quantity of that spills on land during flood to which the beneficial effect can be attributed which otherwise is attributed to the silt deposited with the water.

Dr. S. K. MUKERJI *replies*

The engineering term silt is a little different from the scientific definition of silt, and includes fine sand, silt and clay. Clay particles have less than 0.02 mm diameter and is the active mechanical fraction of a soil responsible for a majority of chemical reactions which go on in the soil. Silt has a very minor role, and fine sand (0.02 to 2 mm) is atmost inert.

The soils of the riverine areas of plains of West Bengal are generally lighter in texture compared to the areas situated away from the rivers. If the irrigation or flood water is rich in clay fractions, the pores on the surface of the paddy soils get choked up. The lighter paddy soils are helped by better stagnation of water and thus improve productivity of the land for paddy. If however the flood water brings down more silt and less clay as happens in the North Bengal rivers, water stagnation is hampered and crops do not derive any benefit. If the deposit of silt and clay is very heavy, as often happens in the Tista valley, the good soil may be buried out of reach of feeder plants of paddy and crop yield goes down.

The conception of local belief has therefore to be considered in terms of the crop grown, situation, nature of the deposit and the kind of the soil which receives the discharge.

Since the D.V.C. water will be obtained through a system of dams and barrages, it is expected that the state of West Bengal will receive the clay fraction more. Since the area grows paddy, we can conclude that building up of soil fertility of poorer light soils is almost a certainty.

Coal Resources Development of Damodar Valley Coalfields of West Bengal

By A. LAHIRI

WEST Bengal covers an area of nearly 31,000 square miles with an estimated population of 27 millions. This high density of population together with a comparatively low acreage of arable lands available for agriculture have led to a situation which can only be helped by intensive industrialisation of the State.

However, the resources of the State on which industrialisation must be based are extremely meagre except for one important item, viz., coal. Industrial development based on agriculture, such as jute, has probably passed its peak. Industrialisation in the field of textiles and others can at the best offer little relief. On the other hand, the coal resources of the State are considerable. With the availability of water, port and transport facilities, coal, can, however, make a substantial contribution to the industrialisation of the State. The present paper gives an idea of the role that coal can play in solving the industrial problems of the State.

The coal-bearing tracts in West Bengal are spread over the districts of Burdwan, Bankura, Birbhum and Darjeeling. Except the last the rest forms part of the Raniganj coalfield—one of the most important coal-bearing tracts of India, having a large reserve of good quality coal both caking and non-caking. The reserves for this field of "good quality" coals (i.e. coal with average 16 per cent ash on moisture free basis and occurring in seams of 4′ thickness and upto a depth of 2000′) alone will be about a third of the total estimated Indian reserves of 5,000 million tons.

Raniganj Coalfields

The Raniganj coalfield is the easternmost part of the Damodar Valley coal-bearing area, and is located around Asansol about 130 miles north-west of Calcutta. The major portion of this field lies to the east of the Barakar river in the western part of West Bengal, but smaller tracts in the west, south and northwest pass beyond this State into Bihar. The coalfield within West Bengal is known to lie between longitude 86°-48′ and 87°-22′E., latitude 23°-51′ and 23°-32′N. (Plate I) and covers about 372 square miles. The coal seams of the Raniganj coalfield occur in the sedimentary beds of Lower Gondwanas ranging in age from 180 to 300 million years. The upper beds (Raniganj Measures) are known to contain more numerous seams than in the lower beds (Barakar Measures).

The coals of the Raniganj coalfield fall into three main classes :

(*i*) Good quality coking and semi-coking coals ;
(*ii*) Good quality weakly caking and non-caking coals ; and
(*iii*) Fairly low rank and high ash inferior class of coals.

The coals of the first type, viz., good quality coking and semicoking coals are largely confined to the seams of the lower beds in Barakar Measures and to a few of those of the upper beds in the Raniganj Measures, particularly in the western sector of the field.

These coals have relatively low moisture ranging from 1-2 per cent (on air-dried samples), moderately high volatile matter and of variable ash. The ash is low in the seams occurring adjoining the Barakar river and yield good coke when carbonised either by itself or when blended with low volatile caking coals. These coals, although suitable for coking have been largely utilised for non-coking purposes, particularly for steam generation and railway locomotives, although a limited quantity has been used in blends in the Steel Plants. In the Table below some typical analyses of such coals are given :

TABLE I

Seam	*Air Dried Basis*					
	Moisture %	*Ash* %	*V.M.* %	*F.C.* %	*Caking Index (B.S.)*	*Cal. Value (B.t.u./lb.)*
Damagoria (Salanpur A)	1.2	14.8	22.5	61.5	Caking	12,870
Kasta	1.8	19.5	33.2	45.5	15	11,340
Bahira	1.5	14.6	26.3	57.6	Caking	12.840
Laikdih	1.1	12.7	30.4	55.8	24	12,990
Ramnagar	1.3	12.6	30.3	55.8	20	12,840
Begunia	1.1	14.9	30.1	53.9	21	12,350

The coals are low in sulphur and in several cases are also very low in phosphorus. The Laikdih, Ramnagar and Begunia seams in particular, contain the best of the potential caking coal reserves of the State. Of these, the thick Laikdih seams have been severely damaged in some areas due to igneous rock intrusions. These have been exploited on a fair scale.

The coals have mostly higher volatile matter than corresponding coking coals of the Jharia field, and also give higher yields of tar and gas on carbonisation.

The investigations at the Fuel Research Institute and the Coke Research Committee at Jamshedpur have shown great potentialities of use of these coals for metallurgical industries. Attention is drawn to the recent publication of the Fuel Research Institute on "Metallurgical Coke from Raniganj Coals" in this connection.

Largely based on these findings, the West Bengal Government have formulated their plans for the establishment of a large coke-oven plant integrated with power production and gas transmission. The advantage of high yields of tar and benzol would also be taken for development of chemical industries.

The fact that these coals with small amounts of low volatile coking coals from the Jharia coalfield or with low temperature char can produce coke of metallurgical quality, is a matter of the highest importance to to the State.

Coals, such as Dishergarh coals, which are now being used for production of gas coke, have been shown to be suitable for production of coke, if suitably blended. *Thus, it is now possible to plan for production of steel as well as coke in this State on almost a self-supporting basis, as far as coal is concerned.* Blends containing 75-80 per cent of local coals will be used for production of coke in the Government Steel Plant at Durgapur. In view of the researches, it is now also possible to plan for doubling of the Steel Plant as is being seriously considered by the Government in the Third Five-Year Plan.

Apart from the demand of coke for Steel Plant, there is a very large demand for hard coke in the West Bengal State for its numerous foundries. With the availability of pig iron and steel, the activities of the foundries will also be largely increased. *A statistical survey carried out sometime ago by the Fuel Research Institute showed that there was an acute shortage of hard coke in the State.* And, it is for meeting this demand from small and medium industries that the Government of West Bengal planned the Durgapur Coke-Oven Project.

Calcium Carbide Manufacture

Researches have further shown that by suitable technique of blending of coals and by special techniques of cleaning, some of the coking coals of West Bengal *can be upgraded for production of special types of coke possessing very low ash* (10-12 *per cent*) *and low phosphorus* (*less than* 0.05 *per cent*) which is essential for ferro-alloy production and for manufacture of calcium carbide. The coals of the Laikdih seam can be specially treated in this manner for production of coke for manufacture of calcium carbide. The production of calcium carbide is at present hampered by the lack of suitable coke in the country. Against an estimated demand of 26,000 tons per annum, there is only one plant in India located in Calcutta area, which can produce about 2,000 to 3,000 tons only. Manufacture of calcium carbide also requires power of the order of 3,500 to 4,500 kW. hour/ton. With the availability of power from hydro and thermal sources and of the possibility of production of special grade coke for this purpose at Durgapur, *development of calcium carbide industry in the area can be confidently undertaken.* Limestone which will have to be imported is also available from not too distant sources.

Ferromanganese manufacture

India also exports manganese ore of high grade quality. It is known that if instead the manganese was exported in the form of ferro-manganese, not only there will be larger accrual of foreign exchange, but also larger profits. As against the export price of Rs. 180 to Rs. 200 per ton for high grade manganese ore, the sale value of 80-85 per cent ferromanganese is nearly Rs. 1,000 per ton. Plans are being made for manufacture of ferromanganese by electrolytic or electric processes in other parts of India. This also requires large quantities of power and also fairly large quantities of special types of low phosphorus low ash coke. Thus, in view of the availability of power and possibility of preparing such coke, manufacture of ferromanganese by electrolytic or electric processes can also be undertaken in the Damodar Valley. *This is all the more feasible now, in view of the fact that large deposits of manganese ore are reported to have been discovered in the Bankura District.*

Manufacture of ferromanganese by electrolytic or electric processes is fairly expensive—reported to be of the order of Rs. 600-700 per ton. On the other hand, manufacture of ferromanganese by the blast furnace technique is considerably cheaper. The fact that all the projects under consideration in India for ferromanganese manufacture is based on electric power, *is due to the belief that suitable quality of low phosphorus coke cannot be produced in India.* The publication referred to above shows clearly that this is no longer the case. *Cokes of suitable type can be produced on a large scale, if desired, and production of ferromanganese by the blast-furnace technique undertaken.*

The Durgapur ovens which have been planned for doubling can easily produce such coke if the authorities decide to locate a ferromanganese plant in this area. The quality of the coals suitable for production of such coke can further be improved by blending with the remaining resources of low phosphorus coals of Giridih.

In view of the difficult foreign exchange position of the country and in view of the very large demands of ferromanganese abroad (in Germany, Japan as well as the United States), the production of ferromanganese in the Raniganj coalfields should receive particular attention.

Semi-caking and Non-caking Coals

As has been pointed out above, the semi-caking and the non-caking coals largely occur in the upper coal Measures of the Raniganj coalfield. The major coal

seams of the Raniganj Measures are given below, the first seam being the bottom-most in occurrence.

1. Gangutiya	Taltore (4′ to 6′)
2. Sanctoria	Poniati (6′ to 18′)
3. Hatnal	Koithee (3′ to 12′)
4. Dishergarh	Dhasul Chichuria (?) Samla Govindpur (3′ to 18′)
5. Sripur	Jote-Janaki-Chowkidanga-Dobrana-Sonepur-Manderboni (8′ to 22′)
6. Burradhemo Raghunathbatty	Monoharbahal-Rana-Satgram-Toposi-Kendchora-Purushottampur (8′ to 22′)
7. Lower Dhadka	Naramkure-Sanctoria-Bonbahal (?) (3′ to 15′)
8. Borachak	Nega-Jemeri-Raniganj-Lower Kajora (9′ to 22′)
9. Gopalpur	Upper Dhadka-Satpukhuriya-Ghusick-Searsol-Upper Kajora (4′ to 20′)
10. Bharatchak	Narsamada (4′ to 10′)

These coals have comparatively higher percentage of moisture ranging from 3-10 per cent and the ash in most of them range from 12-22 per cent. The coals have high volatile matter ranging from 29-37 per cent, and in the pure coal substance often lying between 39-42 per cent. Of these coal seams, those occurring west of Asansol are generally caking in quality, and those to the east are weakly caking or non-coking.

The characteristics of some of the coals of the Raniganj coalfields are given in Table (2).

The coals from the Western part of the Raniganj coalfield, such as those from Dishergarh and Sanctoria seams, are some of the best coals in India. They are extensively used as steam coals as well as for export. They are also practically the only coals used for gas manufacture. Due to the high volatile content and also the low ash, these coals yield large quantities of tar and gas on carbonisation at low, medium and high temperatures. The Gas Companies at Calcutta and Bombay exclusively use these coals for their purposes.

Investigations at the Fuel Research Institute have, however, shown that *these coals can also be carbonised for production of metallurgical coke.* Even the weakly caking seams, such as Poniati and Hatnal can be used in blends with some quantity of low volatile Jharia coals for production of metallurgical coke. In view of the general shortage of coking coal resources of the country and in view of the heavy production programme of steel, it is expected that larger uses will be made of these coals for blending.

The striking feature of these coals is that they progressively lose their coking property as the seam traverses from west to east. At the same time, there is a corresponding increase in oxygen content and moisture in these coals.

In the eastern part of the field, where the oxygen and moisture contents are high, *the coals are liable to severe deterioration in storage and spontaneous combustion.* In complete working out of these seams, considerable precaution has to be taken during the depillaring to prevent fire due to premature collapse and spontaneous combustion. It is reported that very large quantities of coal in the Jambad-Bhowla seam are in danger unless precautions are taken to extract the coal by hydraulic stowing with sand or rock. It is, however, reported that there is a shortage of stowing materials in this area and a committee has been appointed to enquire into the possibilities of procuring stowing materials in this connection. However unless some concerted and quick action is taken, such as by providing a central ropeway system for delivery of sand, boiler ash, slag, etc., very large quantities of coal may be lost, and production of coal from these seams will be severely hampered.

Steam-generation

Many of these coals are possibly the best steam raising coals available in India. It is, therefore, strange that in the plan for increased production of coal for loco and steam generation purposes, scant attention has been paid by the planning authorities for increasing production of coal from this area. Out of a total target of 23 to 24 million tons of coal in the public sector and private sector during the Second Five-Year Plan period, a mere five to six million tons have been allotted to this coalfield. It is known, however, that it will be extremely difficult to replace the good quality coking coals which are now being utilised by the Railways, by equally good non-coking coals when the former are taken over by the Steel Works. A survey of the resources of coal in other areas have shown that *so far few areas have been explored which contain noncaking coal of better quality than in the Raniganj coalfield.* In view of the above, it is felt that greater attention should be paid by the authorities concerned as well as by consumers of quality coals, for increasing production of coals of non-caking quality from these areas.

Problem of Slack Coal

A large part of the non-caking coal of these areas are consumed for locomotives and hand-fired boilers requiring coal of lump size (1″ and above). The Run-of-Mine products, however, contain 30 per cent or more coal below 1″ in size and these are difficult to dispose of. Often these coals are of better quality than the lump coal as due to the concentration of the vitrain (brights) part of coal, the ash content is 3 to 4 per cent lower than in the Run-of-Mine or in the lump size. The only avenue for utilisation of these small size coals is in power stations suitably designed to burn slack coal or pulverised fuel. In the past, difficulties have often been met with due to lack of suitable market for such coals. As has been pointed out earlier, the coals from this area are particularly liable to spontaneous combustion. These unsold dumps in the mines not only lead to economic losses to the mining concerns, but also to dangers of fire in stacks which are liable to spread to the seams.

It is, therefore, desirable that avenues should be explored for utilisation of the slack coal in thermal power stations suitably designed for pulverised fuel burning as well as in other projects.

In this connection, attention may be drawn to the fact that the West Bengal Power Station of 60,000 kW. at Durgapur had been designed for utilising such coals or even inferior quality (upto 35 per cent ash and 10 per cent moisture) with high efficiencies. The proposed thermal power station of 150 Mega-Watt of the Damodar Valley Corporation would have offered a welcome relief to this situation, but it has been planned to be integrated with the Steel Plant and will now utilise the middlings produced from coals brought from Jharia and the surplus gas from the coke-ovens of the Steel Plants. It is, however, likely that further expansion of power will be made either in the coalfield area or in the Calcutta area. When such projects are considered, *the idea of pulverised fuel firing should be kept in view in order to find an avenue for utilisation for the small size coals from this coalfield.* Indeed, it may be essential for these power stations to do so, as in future there is little likelihood of their obtaining the good quality coals of Dishergarh and Poniati seams to which they have been used to, so far.

Production of Synthesis Gas from non-coking Coals

These coals are very reactive in nature and are suitable for gasification, for production of synthesis gas either for production of ammonia, for fertilizers or soda ash or for production of synthetic oil by the Firscher Tropsch technique. In this technique, the coal is gasified with steam and oxygen for production of carbon monoxide and hydrogen in required ratios, which is then reacted upon a catalyst for production of synthetic oil and chemicals. *Approximately 5 tons of coal yield one ton of oil.* The capital cost is of the order of Rs. 1,000/- per ton of oil produced per year. Thus, at 20 per cent of capital charges and with 5 tons of coal valued say, at Rs. 20/- per ton at site, *the cost of production of one ton of synthetic oil will be of the order of Rs.* 300. Since one ton of oil contains about 280 gallons of petrol, the cost of production of petrol will be of the order of Re. 1/- to Rs. 1. 2. 0. per gallon. This is also the cost of oil at the refinery site based on imported crude. In fact, if the relaxation of As. -/2/- per gallon offered to the petroleum Companies for establishing refineries is taken into account, the cost of imported petrol is of the order of Rs. 1. 5. 0. per gallon.

In view of the fact that the area within a radius of 250 *miles of Durgapur consumes* 40 *per cent of the oil requirements of India, a synthetic oil plant will not only be well sited here, but will offer relief to the miners and serve the great strategic requirements of the country with economic gain.*

Low Temperature Carbonisation and Hydrogenation of tar and benzol :

Apart from Fischer-Tropsch method, there is another technique of producing synthetic oil, but not directly from coal. In this method, coal is carbonised either at low or medium temperatures (500°- 750° C.) to produce substantial yields of tar oils which are then hydrogenated under pressure (450 atms.) for production of diesel oil, motor petrol or aviation gasoline. It will be observed that in this method only 10 *per cent of coal is obtained as oil or tar, but* 70 *per cent of the coal is obtained in the form of semi-coke suitable for use as domestic fuel.* This is commonly known as "smokeless fuel".

Examination of Project Reports by experts in India as well as from abroad has shown *great possibilities of utilising this method for production of diesel oil and motor spirit.* The coals of the Raniganj coalfield yield high quantities of tar—of the order of 20-30 gallons per ton when carbonised at low or medium temperatures compared to the yield of 5-8 gallons per ton obtained in high temperature carbonisation from Jharia coals. An Experts Committee appointed by the Planning Commission went into this question, and after considerable thought and consultations with foreign experts, *submitted a scheme for carbonisation of* 1.2 *million tons of non-coking coals from the Raniganj coalfield for production of* 790,000 *tons of low temperature coke, and hydrogenation of the tar, and benzol (obtained from the high temperature coke-oven plants) for production of* 82,000 *tons of motor petrol and nearly* 40,000 *tons of motor benzol for blending with motor petrol,* 2,000 *tons of phenol and* 40,000 *tons of road tar emulsion per annum.* The scheme was estimated to cost Rs. 20 crores and yield a profit of 12 per cent after meeting all charges including mining, housing and sale of petrol at the current rates.

"Smokeless Fuel" :

In view of the density of population in the urban areas including Calcutta and in view of the continued increase in health hazards due to atmospheric pollution, this scheme merits immediate consideration of the Government, both Central and the State. The scheme has further merit that it will replace coking coals now being used for production of soft coke by the wasteful stack burning method in the Jharia coalfield, which can be upgraded for production of metallurgical coke. The coke produced by low temperature carbonisation of Raniganj coals will also be excellent in quality and will have only 20-25 per cent ash compared to 40-50 per cent ash in the normal soft coke now marketed in Calcutta area. The potentialities of low temperature carbonisation of Raniganj coals are indeed vast if the urban population of West Bengal is taken into consideration. Continued use of cow dung and wood as fuel would really spell future disaster for the land, ultimately.

Chemical Industries

There are also great possibilities for the establishment of chemical industries based on surplus coke-oven gas from the Steel Plants, Coke-ovens and the Low Temperature Carbonisation Plants. Coke-oven gas contains hydrogen and methane as well as various quantities of ethane, propane, etc. Liquefaction of the coke-oven gas and the subsequent distillation can yield hydrogen by the cheapest known method. Since hydrogen is a major factor for production ammonia or synthetic oil or for hydrogenation or production of other organic compounds, any such plant (such as fertilizers or hydrogenation plant, etc., or other synthetic chemical projects) can be based on by-product hydrogen obtained from this source. Even under the present plans, *there will be a surplus production of* 40 *million cu. ft. of gas per day from the Durgapur Steel Plant and about* 9 *mil. cu. ft. per day from the Durgapur Coke-oven Plant.* But, whereas the authorities of West Bengal have decided to distribute this gas in a 140 miles pipeline stretching from Chittaranjan to Calcutta, the Steel Plant authorities are reported to be planning for burning the gas in the proposed D. V. C. thermal power station in the absence of any other scheme.

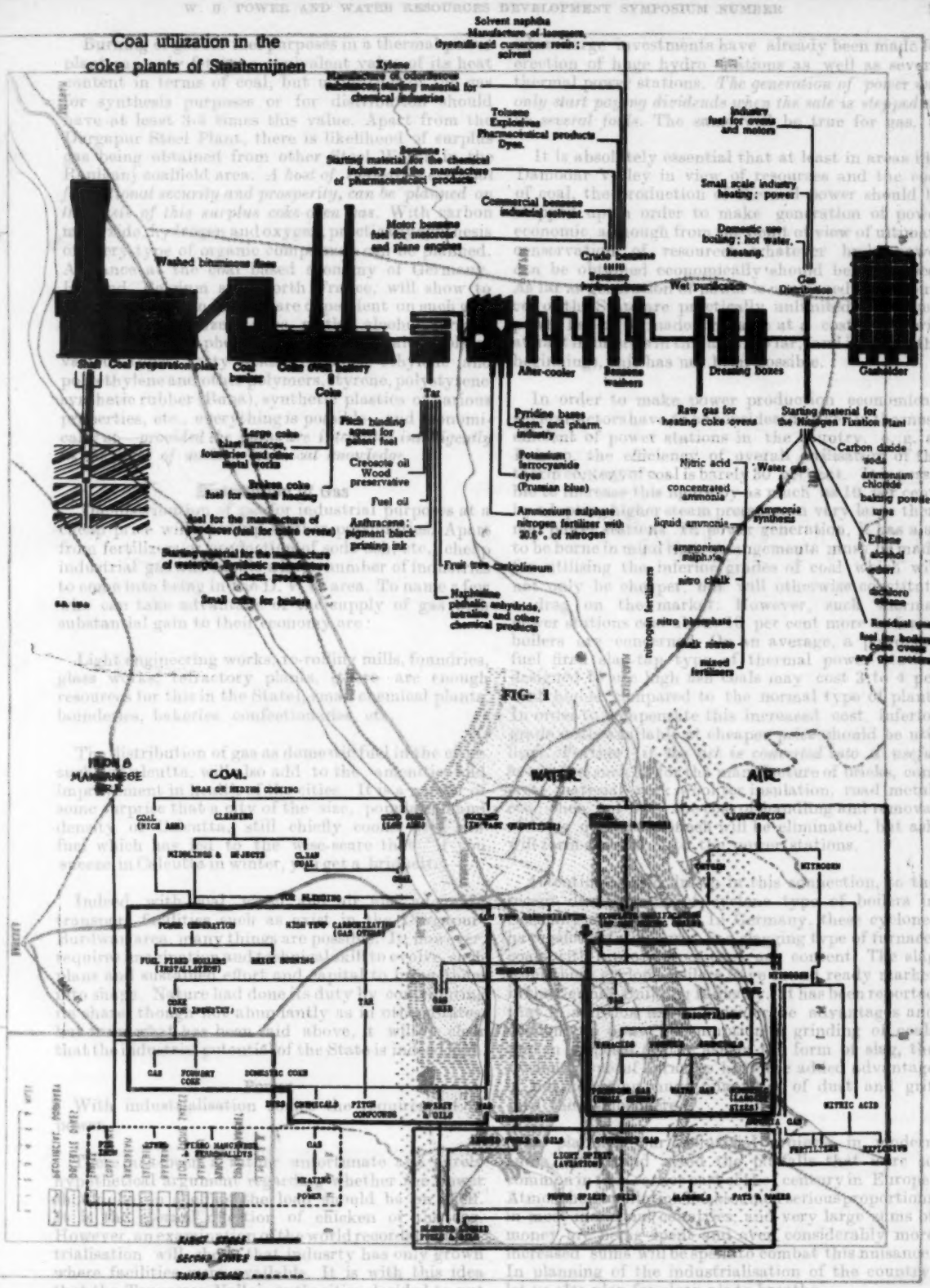


FIG- 1

MAP OF A PORTION OF WEST BENGAL SHOWING THE COAL-BEARING AREA (RANIGANJ COAL-FIELD)

Development of Coal Resources in Damodar Valley (Raniganj Fields)

FIG- 2

MAP OF A PORTION OF WEST BENGAL
SHOWING THE COAL-BEARING AREA
(RANIGANJ COAL-FIELD)

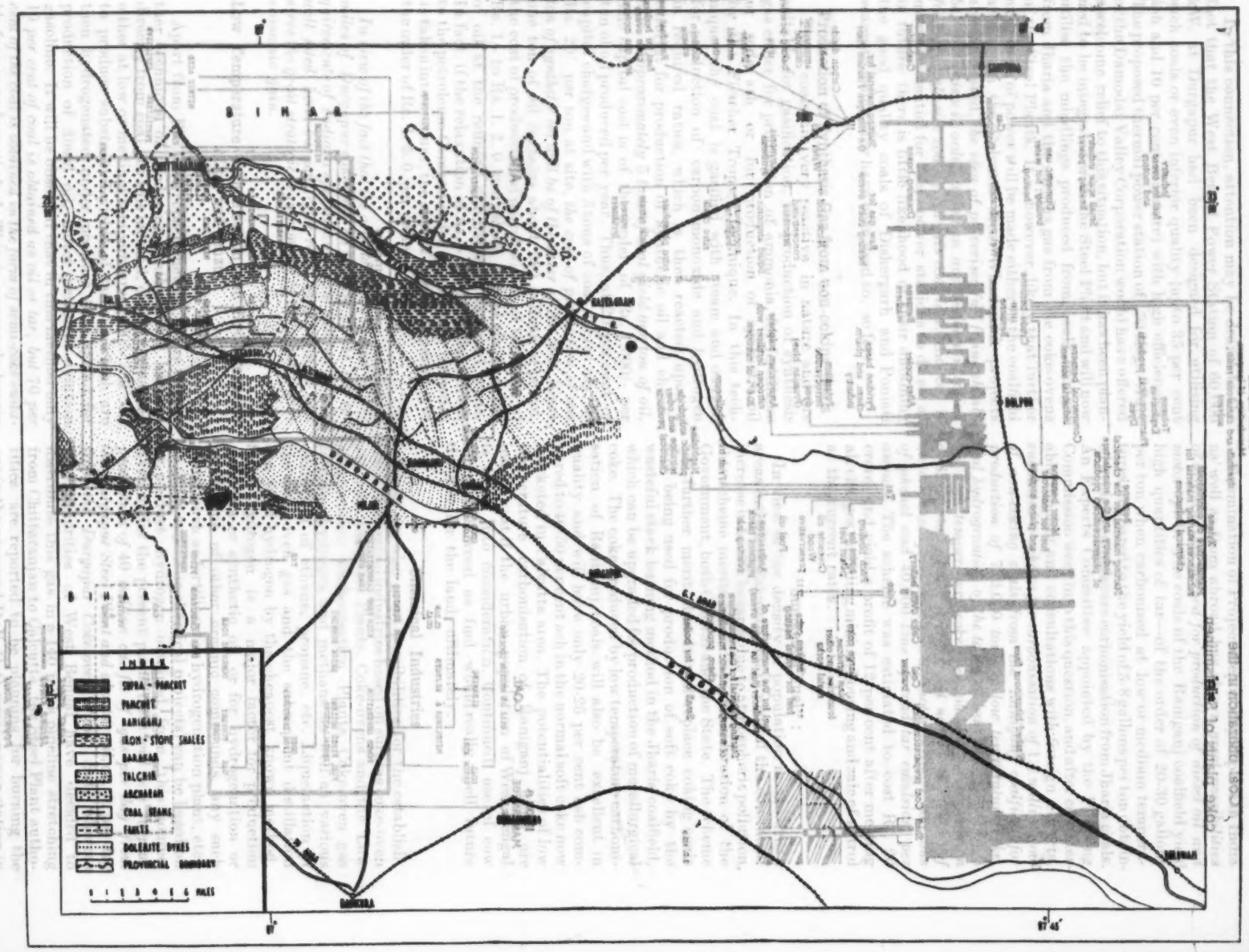


FIG. 3

Burning of gas for fuel purposes in a thermal power plant can only fetch an equivalent value of its heat content in terms of coal, but utilisation of the gas for synthesis purposes or for distribution should have at least 3-4 times this value. Apart from the Durgapur Steel Plant, there is likelihood of surplus gas being obtained from other Steel Works in the Raniganj coalfield area. *A host of industries essential for national security and prosperity, can be planned on the basis of this surplus coke-oven gas.* With carbon monoxide, hydrogen and oxygen, practically synthesis of every type of organic compounds can be planned. A glance at the coal based economy of Germany, Holland, Belgium and North France, will show to what extent the industries are dependent on such gas. Synthesis of fertilizers, urea, methyl alcohol, formaldehyde, phenols, phenol formaldehyde, alchohols of various types, fatty acids, carbides, ethylene and polyethylene and other polymers, styrene, polystyrene, synthetic rubber (Buna), synthetic plastics of various properties, etc., everything is possible—and economically so—*provided the plans are integrated intelligently in the light of modern technical knowledge.*

Distribution of Gas

The distribution of gas for industrial purposes at a cheap price will open up further possibilities. Apart from fertilizers or production of soda ash, etc., cheap industrial gas will enable a large number of industries to come into being in the D. V. C. area. To name a few who can take advantage of the supply of gas with substantial gain to their economy are :

Light engineering works, re-rolling mills, foundries, glass works, refractory plants, (there are enough resources for this in the State), small chemical plants, launderies, bakeries, confectioneries, etc.

The distribution of gas as domestic fuel in the cities such as Calcutta, will also add to the amenities and improvement in health of the cities. It is a matter of some surprise that a city of the size, population and density of Calcutta, still chiefly cooks with raw fuel which has led to the wise-scare that "if you sneeze in Calcutta in winter, you get a briquette.

Indeed, with coal, water and air and adequate transport facilities such as exist in the Durgapur-Burdwan area, many things are possible. It, however, requires imagination and technical skill to evolve such plans and sustained effort and capital to bring them into shape. Nature had done its duty by contributing its share, though not abundantly as in other States, but from what has been said above, it will be clear that the industrial potential of the State is indeed high.

Power

With industrialisation comes the requirement of power.

There has been a rather unfortunate and purely hypothetical argument regarding whether the power should be on shelf or the load should be on shelf. It is the eternal question of chicken or the egg. However, an examination of the world records of industrialisation will show that industry has only grown where facilities were available. It is with this idea that the Tennessee Valley authorities decided to put the power of the shelf and the load has followed. The same, we feel, should be the motto for the D. V. C., where large investments have already been made for erection of huge hydro stations as well as several thermal power stations. *The generation of power will only start paying dividends when the sale is stepped up in several folds.* The same will be true for gas.

It is absolutely essential that at least in areas like Damodar Valley in view of resources and the cost of coal, the production of thermal power should be stepped up in order to make generation of power economic, although from the point of view of ultimate conservation of resources whatever hydro-power can be obtained economically should be harnessed. As far as generation of power is concerned, the resources of the State are practically unlimited. However, power has to be made available at a cost which will attract industries in this area. So far, (and it is only the beginning), this has not been possible.

In order to make power production economical, several factors have to be considered. Even in the most efficient of power stations in the country, e. g. at Bokaro, the efficiency of overall utilisation of the therm content of coal is barely 30 per cent. It is possible to increase this figure by as much as 10 per cent, by adopting higher steam pressures in very large thermal power stations. In power generation, it has also to be borne in mind that arrangements must be made for utilising the inferior grades of coal which will not only be cheaper, but will otherwise constitute a drag on the market. However, such thermal power stations cost about 10 per cent more as far as boilers are concerned. On an average, a powdered fuel fired slag-tap type of thermal power station designed to use high ash coals may cost 3 to 4 per cent higher compared to the normal type of plant. In order to compensate this increased cost, inferior grade coals available at cheaper price should be utilised. Further, *if the ash is converted into a useful by-product* such as for the manufacture of bricks, concrete material, rock wool for insulation, road metal, etc., then not only the cost of handling and removal of large quantities of ash will be eliminated, but ash will form a revenue to the power stations.

Attention is also drawn in this connection, to the recent development of cyclone type of boilers in Germany and America. In Germany, these cyclones have successfully burnt in a slagging type of furnace, coals with (upto) 55 per cent ash content. The slag from these cyclone boilers have found ready market in the German Building Industry. It has been reported that in addition to the considerabe advantages and economy in power consumption in grinding of coals and in disposal of the ash in the form of slag, the cyclone type of furnaces have the added advantage of not ejecting huge quantities of dust and grit into the atmosphere.

In planning our industrial projects in modern India, we should avoid the pit-falls that were so common in the earlier part of the century in Europe. Atmospheric pollution has assumed serious proportions in most industrial countries, and very large sums of money are being spent and even considerably more increased sums will be spent to combat this nuisance. In planning of the industrialisation of the country, let us also plan for clean air to breathe.

As we have pointed above, the generation and

FIG. 3

distribution of gas will be one of the important items in combating this nuisance. If in the domestic hearth or in the industrial furnaces when coal is replaced by gas (generated from it), it will keep our air clean. At the same time, in course of conversion of coal to gas, we can get a host of by-prouducts which will become the basis of our chemical industry.

Manufacture of Acetylene and derivatives

A possibility which has not been mentioned earlier in this paper is the production of acetylene. We have already referred to the production of calcium carbide. Calcium carbide, which is mainly used in this country for generation of acetylene for welding and lighting purposes, is also a major industrial source for acetylene for the chemical industry. Acetylene can also be manufactured now from methane which can be separated from coke-oven gas. Acetylene is the source of a very wide field of chemical industry from rubber to polyvinyl chloride and with the coming of the modern plastic age, the importance of this field of chemical industry cannot be over-rated.

With liquefaction and separation of coke-oven gas for production of hydrogen and methane, will also become available large quantities of ethylene. These can be converted to ethylene and polyethylene type of plastics, which can replace even metals where temperatures in use do not exceed 150°C. Use of polyethylene stretches from manufacture of packing material to insulation of canals for irrigation to avoid seepage and to manufacture of pipes for transmission of gas and chemicals.

The field is, indeed, vast and as stated above, with coal, air and water, and steel and money, much is possible. But, above all, it is the human determination and skill that can decide the issue.

A general scheme of complete utilisation of coal of the Raniganj coalfield is given in the sketch. The Durgapur Project of the West Bengal Government was conceived in the light of this scheme and forms only a beginning of a vast undertaking that is likely to grow up from this humble beginning. This scheme is discussed in greater detail in a separate paper from the Durgapur Project Authorities.

DISCUSSION

P. R. ROY CHOUDHURY:

Dr. Lahiri during his speech stated that the coal deposits in the Raniganj and Jharia Coal-field areas are in abundance, which is considered adequate for generation of power by coal-fired stations for quite some time. All varieties of coal could be used for power generation by designing the boilers suitably.

It is understood that some coal deposits have been found in Bankura district. I would like to know

(*i*) the estimated reserve ;

(*ii*) the analysis of the coal such as Carbon and Ash content etc.,

(*iii*) whether this deposit could be commercially exploited and used for power generation.

(*iv*) whether there is a scheme to develop these collieries in the near future ?

Dr. LAHIRI *replies*

Regarding the questions about the coal deposits now discovered in Bankura, I like to inform you that exploration party of the Geological Survey of India is still engaged in proving the actual extensions of the coal bearing tracts in the area and unless reports from them are finalised, it will be too early to say definitely about the estimated reserves, the quality of coal etc. From what we are aware, 3 seams varying in thickness from 8 to 19′ and occuring within a depth of about 300′ of the surface have been met with in the exploratory boreholes. The characteristics of these seams are such as to warrant their economic exploitation possible when the demand for coal increases in the area. The analysis of borehole cores indicates that the coals are high in ash as most other Indian coals, but it would make their use possible for power generation in suitably designed pulverised coal firing boilers either of the slag bottom or the dry bottom type. Nothing is however known at present about the chances of exploitation of these deposits for power generation. We shall be able to say further about these deposits when more data are available.

Continued from page 87

Future Trend of Power Development in West Bengal

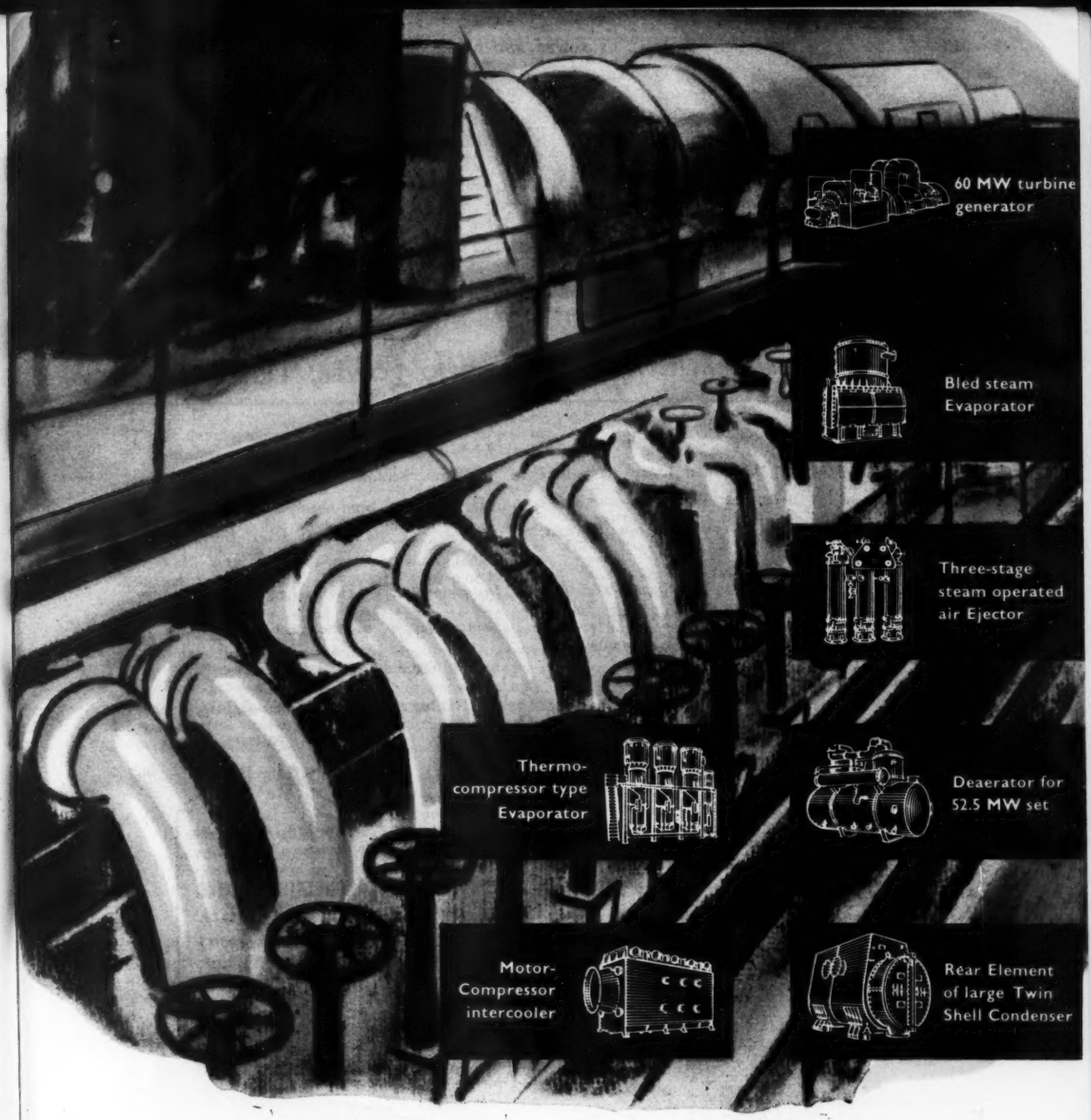
The above proposition is likely to be technically sound. This may, however, be studied in Network Analyser before finalising the scheme.

A. K. BHAUMICK *replies* :

Almost all the advanced countries in the world are now planning ahead for establishing Atomic Power Stations and it would be futile for India to lag behind. As a matter of fact, Dr Bhabha, Chairman of the Atomic Energy Commission recently indicated that India should build atomic power to the extent of 1 million kilowatts within a foreseable future. According to the latest estimate available, an Atomic Power Station with 200 MW costs about 40 crores of rupees against a Thermal Plant of similar capacity costing 20 crores. It is expected that with further experience available all over in erecting these stations, the cost will come down.

By the time an Atomic Power Station is actually built up, the power demand in West Bengal would considerably go up so much so that by 1965 this may go up to 800-1000 MW. It is envisaged that in the near future important grid power systems will have to be inter-connected by erecting a super grid, so that maximum benefit of hydro thermal combination is derived.

As it is envisaged that major power systems will be inter-connected in the long run, it will not be necessary to keep spare plant equivalent to the capacity of an Atomic Power Station. It is true that nuclear generation may not be compared favourably with conventional method of generation for some time to come. For strategic reasons, we must have an Atomic Power Station, particularly for gaining valuable experience for this type of generation.


60 MW turbine generator
Bled steam Evaporator
Three-stage steam operated air Ejector
Thermo-compressor type Evaporator
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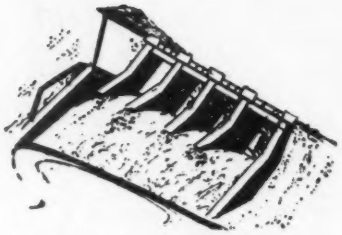

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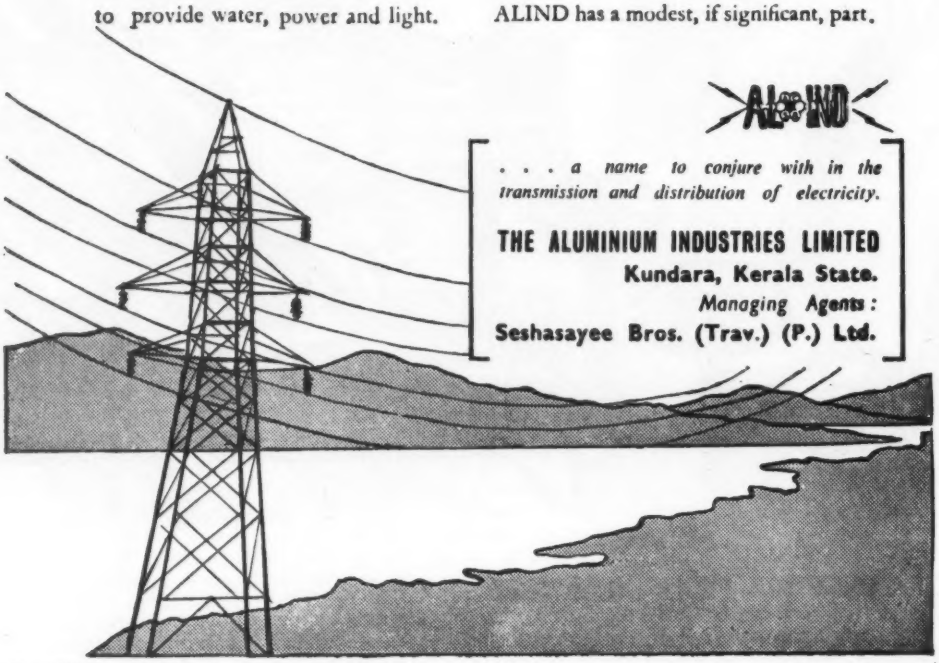

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Water Power Resources of West Bengal

By M. DUTTA

THE development of hydro-electric resources in India, even though she has a large number of rivers spread all over the country, has not been spectacular. Of 30 to 40 million kW of hydro-electric resources in India, only about 0.71 million kW represents hydro-electric power so far developed upto the end of 1953. This development, again, has been mostly in South India. In West Bengal hydro-electric schemes have made very little stride. Of the total power of 552,329 kW obtainable hitherto from the various types of Power Station in West Bengal, only 6,760 kW, representing near about 1.2% of the total power, is obtained from hydro-electric stations. There are only 3 hydro electric stations out of 25 different types of power stations in West Bengal. Curiously enough, Darjeeling in West Bengal claims to be the pioneer of hydro-electric development in India, having started operation in 1897-98.

Two reasons can be advanced for this anomaly :

(1) Comparatively high co.t of developing the water power sites.

(2) Because of the proximity of coalfields West Bengal gets its electricity generated at a cheaper price.

Water power, however, does not necessarily represent a natural source of energy which can be developed at a very low cost. Besides capital cost of harnessing the natural source of energy, the cost of transmission may be also a determining factor. In West Bengal, where both the hydro and thermal power resources are available, the two sources of power may be considered as complementary rather than competitive and ways and means should be found to develop hydro-power in this State, having regard to other effects its construction will have upon the economy of the State.

Rivers of West Bengal

From the point of view of hydro-electric generation, the rivers of West Bengal can be classified into three groups.

Group I: The rivers of the Gangetic plains have their sources in distant mountains. The Gangetic plain being absolutely flat, the rivers of this group cannot be utilised for hydro generation. The Ganges is the largest of this group, draining an average annual rainfall of 42 inches over a catchment area of 397,500 sq. miles with a record discharge of about 2,000,000 cusecs.

In the lower deltaic region, there are a number of estuaries where the possibility of obtaining power from the tides may be explored. But however alluring this may be, the prospect of developing tide as a source of energy at least for the present is disappointing.

Group II : The rivers of this group are the Subarnarekha, the Cossye, the Damodar, the Ajoy, the Mayurakshi etc. The Damodar is the typical example of this type, that causes devastating flood during monsoons and dwindles down to mere trickles in dry season. For irrigation needs in this region storage dams are required; but owing to the flatness of the country, it is difficult to obtatin suitable sites for storage dams within the boundaries of the State; and as such large reservoirs and dams have been built in connection with the Damodar and the Mor projects outside the State of W. Bengal Besides meeting the needs of irrigation, the control of the river by constructing dams would prevent recurrence of floods. There are also being utilised for the production of hydro-electric power. On the basis of this unified development actively executed by DVC and the State Govt. hydro-electric power is to be obtained from Mor and DVC projects at a cheaper price low enough to compare with the cost of power from other sources. Had not this power production been an adjunct of gravity irrigation in these regions, the cost of power would have been very high.

The State Govt. has taken up the implementation of the Kangsabati Reservoir Project as far as flood control and irrigation aspects are concerned during the 2nd Plan period. The possibility of power development is still under investigation. It is expected that about 6,000 kW of power will be available which is to be taken during the 3rd Plan period. This project when completed can be interconnected with the existing transmission system, thereby enabling the utilisation of seasonal power with economy.

Group III : The North Bengal rivers fall under this group—the Teesta and all others which flow east of it

viz. the Jaldhaka, the Raidak, Gangadhar etc. rise from the Himalayan region and flow into the district of Jalpaiguri and Darjeeling. These snow-fed rivers, with heavy rainfall in the region, have great hydel power potential. But the rainfall being seasonal, the inflow of these rivers varies over a wide range during the year round, so that the steady power available being dependent on minimum flow will be quite small in comparison with the size of the river, unless suitable natural storage basins for the water can be located. Hydro projects in this region also needs long flume line and pipe lines to make the necessary hydraulic head for power generation. The landslide problem in this region, again, is a formidable factor. All these would make the capital cost of such project appreciably high. If, however, for the control of North Bengal Flood, any scheme of construction of dams is carried out as with the Damodar, it might be possible to utilise for power production the head of water behind the dams thereby making the cost of power relatively cheaper.

The regions of the northern districts of the State being far remote from the Coalfield areas, the possibility of installation of thermal power plant is ruled out due to the difficulty of transport of coal. Some of the small rivers in the region possess considerable water power potential and it has thus been possible to supply power and energy derived from these sources.

The output of the existing stations at Kurseong (800 kW) and Darjeeling (1640 kW) have become insufficient to meet the ever-growing demand in recent years. The State Electricity Board have, therefore, decided to erect a new power station of larger capacity by harnessing the river Jaldhaka.

Schemes of the Himalayan Regions: Jaldhaka Hydro-Electric Scheme

The reach of the Jaldhaka river between Bindu Khola and Naksal Khola offers good possibilities for development of hydro electric power. A scheme for developing the head in the upper part of this reach (600 to 800 ft.) was prepared by the State Government in 1947 with a view to supplying to numerous tea gardens in the Dooars, involving power transmission over short distances.

The course of the river presents specially favourable conditions for the utilisation of water power in the surrounding territory. Moreover, it has been found possible to develop the river in several stages. Such stage-wise development commensurate with prospective growth of load will not entail heavier financial commitments and can be carried our without becoming a burden.

The Scheme, now under implementation under Second Five Year Plan does not envisage to utilise the full fall from Bindukhola to Naksalkhola but is confined to utilize the upper reach viz. the fall from the Bindukhola to Jhalung Khola. The fall from Paren Khola to Naksalkhola would be utilized at a later stage. The capacity of the pwer station is based on the minimum flow of 270 cusecs and the utilization of the fall from Bindukhola to Jhalungkhola which is the larger of the two and has a head of 650 ft. Two 12,000 kW sets would be installed in the power house. Initially one set would suffice for regional urban and rural electrification and also the tea drying. The second set to be installed later would serve as stand-by during dry months and would run during monsoon to generate secondary power for tea drying.

The fall from Parenkhola to Naksalkhola is about 317 ft. and the minimum discharge is about 290 cusecs. About 8,000 kW of firm power and about 8,000 kW of additional power can be generated by utilizing this fall.

On this river, it is also possible to construct a system of low head power plant with storage basin. The resulting head of water can be utilised for at least six hydro-electric stations to produce 77,000 kW capacity with an annual output of 424 million units. These power plants will be in the heart of the tea gardens and close to the railway lines and as such would provide for an economic source of power near consuming places.

This scheme at the lower reach divided into six stages, is as follows :

Jaldhaka Power Plant

	Location of Plant.	Available head ft.	Maximum discharge cusecs.	Power of plant kW.	Output energy kWh
(1)	Sipchu	90	2,300	15,000	82,800,000
(2)	Taluk	90	2,300	15,000	82,800,000
(3)	Sukhani	60	2,300	10,000	55,000,000
(4)	Nagrakata	60	2,300	10,000	55,000,000
(5)	Talkapara	60	2,300	10,000	55,000,000
(6)	Tandu	70	3,070	17,300	93,700,000
	Total	430	14,570	77,300	424,300,000

The storage basin for the power development does not suffice for storing the enormous quantities of water precipitated during the periods of heavy tropical rain. It was, therefore, proposed to construct a Wier type power station. The weir will consist of certain number of openings allowing the discharge of highest monsoon floods without raising the water level in the head race.

Balasun Hydro Electric Scheme

The generation of hydro-electricity from the river Balasun in the district of D rjeeling was also included for implementation during the Second Plan period; but for paucity of funds the work has to date been deferred. It is estimated that about 4,000 kW of power will be available in wet season but only 2,000 kW during the dry season.

Other Hydro Electric Schemes

Jainti and Katulum River Schemes

The river Jainti and its inflow Katulum run down from Bura hills. It may be possible to construct a dam for an accumulation basin at a level of 2,000

ft. in the case of Jainti river and at a level of 1,650 ft. in case of Katulum river. These rivers have a high fall at a short distance and a good discharge in the dry season also.

The power generating plants of these two rivers can be joined to one power scheme. The Katulum river will be utilised in one stage while the Jainti river needs two stages.

The total capacity will be 11,000 kW and output of energy per year will be about 55,000,000 kWh.

Raidhak River Scheme

The Raidhak river coming out of Bhutan near Bhutan Ghat passes through a narrow gate located in the last chain of hills. This point is close to the boundary between India and Bhutan and is advantageous to the construction of high dam. The basin lies within Bhutan territory but all other construction sare either on the boundary or within Indian territory.

The proposed installed capacity is 75,000 kW for discharge of 3,000 cusecs.

Conclusion

The above is a short account of water power generation and its possibilities with special reference to the State of West Bengal. It is for the State Government and the Government of the Union to consider the present condition of power generation as well as its future development for its effective utilisation and no money spent for the purpose will go in vain.

Integrated effort should be made by all departments connected with the development of the rivers of West Bengal, such as Irrigation, Power, Flood Control, Navigation etc. so that all round development of the State can be achieved with maximum economy.

DISCUSSION

P. R. ROY CHOUDHURY:

As per preliminary load survey recently conducted in areas proposed to be commanded by the Jaldhaka hydro-electric scheme, load is estimated as follows :

At the end of :

(*i*) 2nd 5-Year Plan (1960-61)—3177 kW of which Tea Gardens account for 1000 kW.

(*ii*) 3rd 5-Year Plan (1965-66)—7556 kW of which Tea Gardens account for 4500 kW.

(*iii*) 4th 5-Year Plan (1970-71)—10792 kW of which Tea Gardens account for 7000 kW.

Available capacity of Jaldhaka as now planned is 12,000 kW firm and another 12,000 kW seasonal. The above when added with the existing hydro-electric installations in that region will work out to 14,440 kW of firm power.

Tea gardens in that region are widely scattered. It may not be possible to supply electricity to more than 45% of the gardens economically without asking the owners of the gardens to pay for the cost of the extension. This may be a deterrent factor in the development of load in the tea gardens as anticipated, if adequate fund is not provided for transmission and distribution of power from the Jaldhaka Scheme by the sponsors of the project. Apart from it, the following may also impede load development in the tea gardens :

(*i*) divergent views on the use of electricity in lieu of conventional way i. e. by heating the air chamber by coal, wood and diesel oil etc. for roasting of tea;

(*ii*) installation of new diesel engines by some garden owners.

There is a possibility of considerable amount of power being surplus in the Jaldhaka scheme, unless special efforts to develop the load by offering competitive rate particularly in case of tea gardens are made long before the scheme starts functioning. Rate at which power could be sold to ultimate consumers may be indicated before the scheme is brought into operation.

I am interested to know the tariff and the utilization scheme of Jaldhaka power.

It has been stated that hydro potential of Teesta Valley is of the order of 300 MW. Where is the market for this power, if developed? Hydro-electric development in northern part of West Bengal should start simultaneously, if not preceded by industrial development scheme of the region.

Whether the scheme is technically feasible and export of power from this area to the Calcutta region through a high tension line could be economically done may be studied carefully as a part of the investigation before the hydro-electric development schemes in North Bengal are embarked upon.

Dr. DATTA *replies*

Maharaja of Bhutan while issuing permission for carrying out hydrological survey in their territory has expressed his willingness to purchase electrical power for the development of his country when Jaldhaka Project comes into operation. Though we have little knowledge regarding load prospects in Bhutan area still the very interest which a country like Bhutan has shown may be considered a very good sign.

Before submitting the project report we had correspondence with the Secretary, Indian Tea Board Association regarding the expected load demand of the tea gardens in the Dooars Area. The Secretary, in reply, furnished us a complete list of the gardens willing to purchase power from the proposed Jaldhaka Grid. Of course, all of them would not be connected at the very beginning but it would not be optimistic to expect more than 50% of them connected within a period of ten years.

From our experience of Kurseong Hydro-electric Supply where service connection had to be very much restricted for want of sufficient generating capacity

it can safely be assumed that entire North Bengal has a huge demand for electrical power. Apart from Tea Industry there are ample scope for the growth of other industries like saw mill, paper mill, rice mill, machine shop, power loom etc. Due to inadequate transport facilities the price of coal etc. which are essential for the growth of industries the development programme in the northern part of West Bengal has been greatly hampered. Electricity is the only tool which can give a start and *remove* the deadlock condition; once it is started demand for electrical load will go on increasing in geometrical progression.

In order to enable growth of load, the West Bengal State Electricity Board have already started electrification in towns like Mekliganj, Changrabandha, Mathabhanga, Haldibari and Malbazar by installing Diesel Generating plants. As the cost of generation of Diesel Station (viz. at Siliguri, Cooch-Behar, Jalpaiguri, Darjeeling and Kalimpong) is very high the Board is experiencing great difficulties to help growth of industrial loads in those areas. With the advent of cheap electrical power from the Jaldhaka project such industries would grow rapidly ensuring all round development of this northern region.

Teesta Valley Development Scheme, a multipurpose one, has been drawn up with an estimated cost of Rs. 75.00 crores and envisages to generate 1200 MW of electrical power (firm power 600 MW). It is true a market for such a hydro power could not be foreseen in Northern Bengal within the coming two decades. As such, it is proposed to export this power to Calcutta and to the future industrial areas encircling Durgapur. In Durgapur, installation of two power stations is already settled. Moreover the DVC grid passes through this industrial area and one may reasonably ask justification of importing further power. From the load estimates of DVC, Durgapur & Calcutta with suburbs we can certainly justify this necessity. Moreover, in the development programme of our country coal plays a very important part. Leaving aside the need for first grade coal for metallurgical purposes the demand for middling and low grade coal is also very high and this demand will go on increasing till electricity come to its rescue. Considering all these above factors it is advisable to save coal as much as we can and atleast on this ground we find no other alternative but the Teesta Valley scheme to save the situation by meeting the future load demands of Calcutta with suburbs, Durgapur and the rest of West Bengal.

Execution of Teesta Valley Project would require a huge amount of construction power. The idea of meeting this demand by installing Diesel Generating Sets seems ridiculous. Jaldhaka Project can only help the situation.

Continued from page 110

Flourishing Sundarbans

inhabitants. Owing to the many rivers, construction of roads and railways would be costly; but the deepened rivers would provide perennial navigation, so that the inhabitants could easily carry their produce in boats to the most profitable market, which will be an inducement for them to grow more crops.

With 5 acres of land allotted to each family 128,000 families or over 500,000 refugees from East Bengal could be rehabilitated in the 640,000 acres of the newly reclaimed land. These refugees, who are accustomed to low lands and rivers, will provide all the labour for the reclamation works. For each mile length of a river, 16 gharamies, 4 carpenters, 40 khalasies, 24 boatmen, 2 large boats and 6 small boats are necessary. For the 'permeable screens', the material needed are bamboos and brickbats for the 4 weights in each unit. For the sluices, timber planks are necessary. These are all locally available. Other materials, $\frac{1}{4}''$ mild steel rods for joints, and expanded metal for making small cages for brickbats for the weights are available in the market at Canning or Calcutta.

The cost of narrowing, deepening, canalising and stabilising each mile length of the Sundarban rivers, will be between Rs. 3 and Rs. 8 lakhs. The cost of reclamation of one sq. mile is between Rs. 6 and Rs. 16 lakhs, and of one acre between Rs. 950 and Rs. 2,500. For the 1.000 sq. miles, the cost is about Rs. 112 crores.

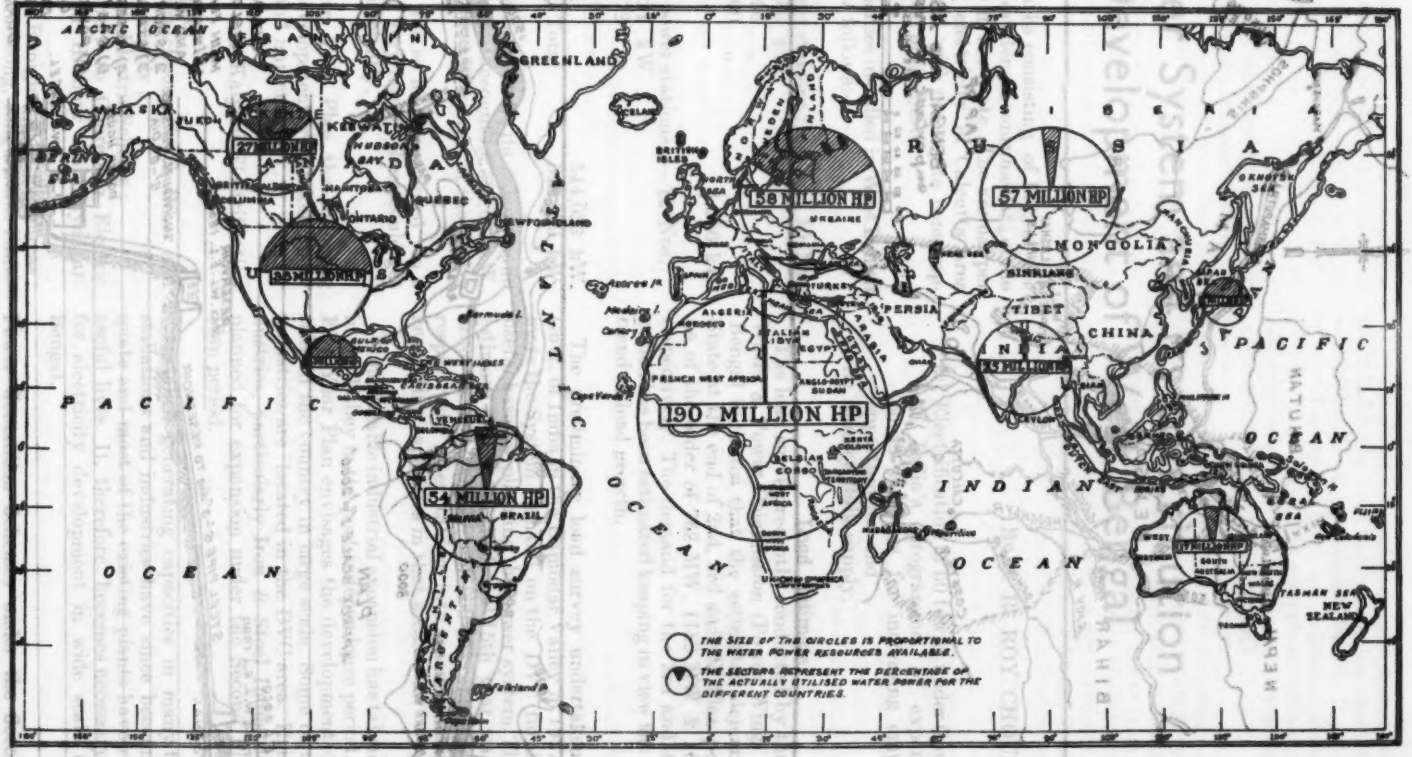
Restoration of Prosperity to the Sundarbans

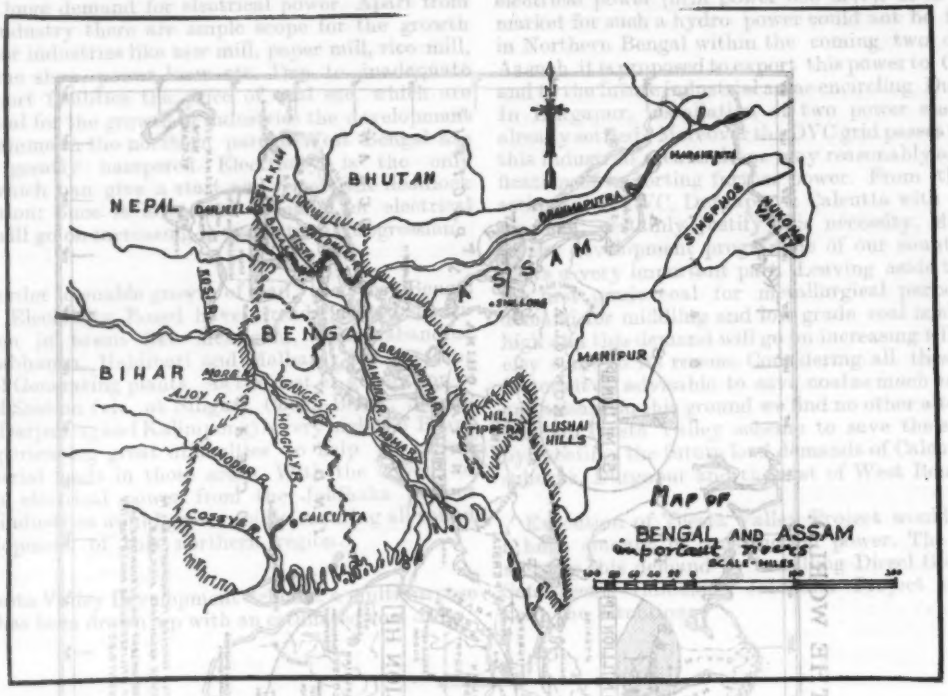
With proper maintenance of 2201 miles of bunds in the 1172 sq. miles, growth of crops in each acre of land will be ensured, the annual value being about Rs. 16 crores. As already explained, 'permeable screens' will keep the cost of maintenance within Rs. 14 lakhs, which may be met from the revenue of Rs. 25 lakhs. The one million inhabitants will become prosperous.

The 640,000 acres, reclaimed from the balance 1828 sq. miles of the Sundarbans, will produce crops worth Rs. 14 crores annually. The expenditure of Rs. 112 crores will thus be financially justified, while rehabilitation of 500,000 East Bengal refugees in land suitable for them will be ensured. Once more, the granary of Bengal will be :

The Flourishing Sundarbans

WATER POWER OF THE WORLD.

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PADMA R.
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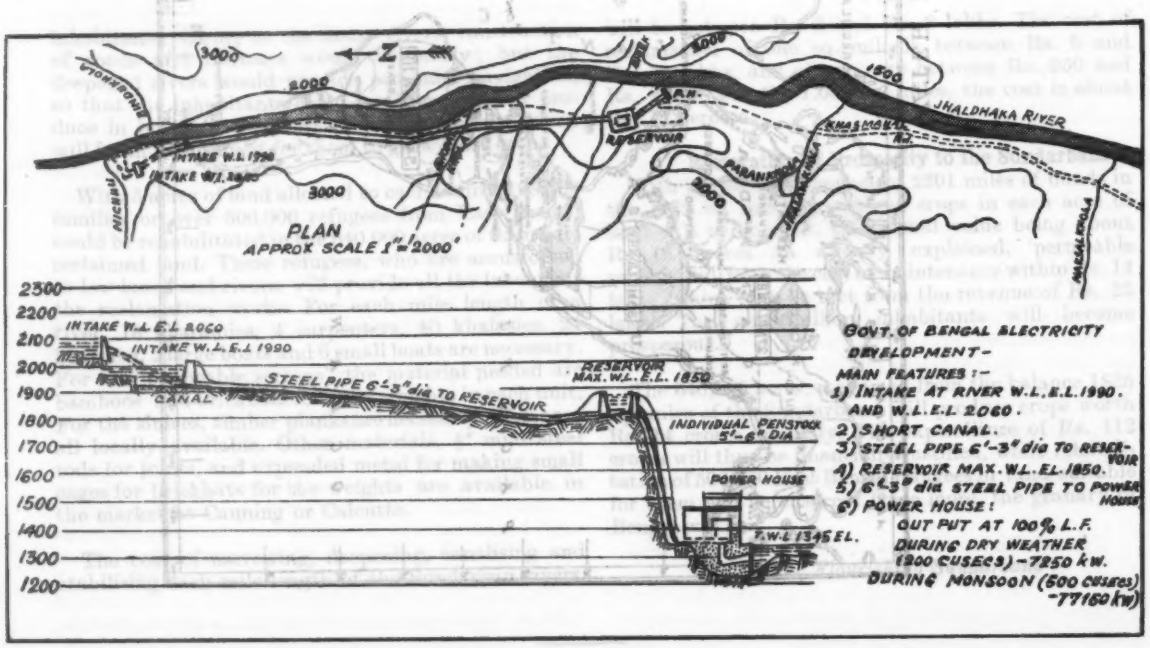
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JHALDHAKA RIVER
KHASMOWA
RESERVOIR
PARANPUR
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APPROX SCALE 1"=2000'
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INTAKE W.L. E.L. 2060
INTAKE W.L. E.L. 1990
CANAL
STEEL PIPE 6'-3" dia TO RESERVOIR
RESERVOIR MAX. W.L. E.L. 1850
INDIVIDUAL PENSTOCK 5'-6" DIA
POWER HOUSE
T.W.L 1345 EL.
GOVT. OF BENGAL ELECTRICITY DEVELOPMENT-
MAIN FEATURES :-
1) INTAKE AT RIVER W.L. E.L. 1990. AND W.L. E.L. 2060.
2) SHORT CANAL.
3) STEEL PIPE 6'-3" dia TO RESERVOIR
4) RESERVOIR MAX. W.L. EL. 1850.
5) 6'-3" dia STEEL PIPE TO POWER HOUSE
6) POWER HOUSE:
OUT PUT AT 100% L.F.
DURING DRY WEATHER (200 CUSECS) - 7250 kW.
DURING MONSOON (500 CUSECS) - 17160 kW.

DVC Power System and its contribution towards Development of West Bengal

By P. R. ROY CHOUDHURY

CALCUTTA and suburbs consisting of 18% of the total population of West Bengal consume 81% of the total energy consumed in the State. The annual per capita consumption of electricity in Calcutta area is 303 units as compared with per capita consumption of 12 units in the rest of the State.

Total generating capacities installed in West Bengal (Ex DVC System) are as follows:—

(*a*)	State-owned power stations :		10 Nos.
(*i*)	Steam	800 kW.	
(*ii*)	Oil	2,696 ,,	
(*iii*)	Hydro	800 ,,	
	Total		4,296 kW.
(*b*)	Privately owned power stations :—		12 Nos.
(*i*)	Steam	540,221 kW.	
(*ii*)	Oil	2,172 ,,	
(*iii*)	Hydro	1,640 ,,	
	Total		544,033 kW.
	Grand Total		548,329 kW.

Out of the above, Calcutta with its suburbs and the industrial areas of Asansol account for 538,625 kW. leaving the balance of 9,704 kW for rest of the State.

Supply of electricity was so long restricted to a few municipal towns and very few of them could get supply adequately and efficiently.

During the First Five Year Plan the following schemes for electricity development were taken up by the State Government and implemented :

(*i*) North Calcutta and Kalyani Electrification Schemes ;
(*ii*) Diesel Electric pool ;
(*iii*) Extension of Barrackpore, Cooch Bihar and Dinhata Electric Supply ;
(*iv*) Mayurakshi Hydro Electric Scheme ;
(*v*) Bulk power supply to Gourepore Electric Supply, Diamond Harbour and Jaynagar-Majilpur towns ;
(*vi*) Power supply to Raniganj Coal-field areas ;
(*vii*) Acquisition of Kurseong, Siliguri and Santiniketan Electric Supply Co ;
(*viii*) Sonarpore-Arapanch Drainage Scheme ;
(*ix*) Community Development projects including Tubewell irrigation ;
(*x*) Electrification of 60 towns under Government of India's programme of expansion of power facilities for increasing employment opportunities and
(*i*) Sundry Bulk supply.

Load Estimate

The load survey recently conducted by the Central Water & Power Commission (Power Wing) in West Bengal indicates that the estimated demand of the State at the end of 2nd, 3rd and 4th Plan period will be of the order of 762 MW, 1183 MW & 1685 MW respectively. The demand for the 3rd and 4th Plan period has been estimated keeping in view the previous trend of load growth.

The preliminary load survey undertaken by the Govt. of India in the Damodar Valley in 1947 to estimate the System Demand on the DVC furnished an useful base for planning the power system. Their load estimate during 5th, 10th and 15th year was of the order of 282,000 kW, 459,000 kW and 550,000 kW respectively after taking into account the available generating capacities in that area.

Considerable industrial expansion has taken place in in the Valley in the post-independence period. Second Five Year Plan envisages the development of industries in the country in large scale. Some of the large industries are located in the DVC area. Existing industries, particularly Iron & Steel Industries, have planned for expansion under the Second Five Year Plan period.

Installed generating capacities in many town installations and industries have since become inadequate and most of the existing plants have run their useful lives. It, therefore, becomes necessary to plan for electricity development in wide scale in West Bengal.

Power Generation Schemes under the Second Five Year Plan

The following schemes for generation of power in West Bengal except DVC System have been included under the Second Five Year Plan.

State Government	
(*a*) Thermal Stn. at Durgapur	60,000 kW.
(*b*) Hydro Electric Schemes in North Bengal.	
(*i*) Jaldhaka	17,000 kW.
(*ii*) Balasun	5,000 kW.
Total	82,000 kW.
(*c*) Privately owned. Calcutta Electric Supply Corporation.	50,000 kW.
Grand Total :	132,000 kW.

Balasun hydro-electric scheme has since been deferred for paucity of funds. DVC Power System as now planned and sanctioned includes the installation of two thermal power stations one at Bokaro (installed capacity 225,000 kW and other at Durgapur (installed capacity 150,000 kW) with an aggregate installed capacity of 375,000 kW and the three hydro electric stations at Tilaiya (4000 kW), Maithon (60,000 kW) and Panchet Hill (40,000 kW) with an aggregate installed capacity of 104,000 kW.

Total installed capacity of the system works out to 479,000 kW with a firm capacity of 352,000 kW.

The transmission and distribution system of the DVC extends to Patna Dalmianagar in West and Howrah in East and comprises of :

(*i*) 132 kV D/C Transmission Line	803 miles
(*ii*) 132 kV Grid Substation (inclusive of power station switchyard).	19 nos. where 49 transformers with an aggregate capacity of 1,475,000 kVA are proposed to be installed.
(*iii*) 33 kV sub-Transmission line.	102 miles.
(*iv*) 33 kV Receiving Stations.	13 Nos

As the anticipated demand on the DVC System at the end of Second Five Year Plan will fall short of available capacity, there is likely to be a shortage of power in the system unless this is made up either by generating more power in the Valley or by importing the same from the neighbouring power systems. This is now receiving the active consideration of the authorities.

Schemes for Utilization of DVC Power in West Bengal

The Damodar Valley Corporation Act vests the Corporation, a statutory body formed in July 1948 on the model of Tennessee Valley Authority and joint enterprise of the Central and State Governments of Bihar and West Bengal, with the task of promotion for operation of the schemes for generation, transmission and distribution of electric energy in the Damodar Valley as an incidental to the primary objective of controlling the flood in the Damodar in lower valley. The Corporation is not empowered to sell electricity below 30,000 volts under the Act. The Act also restricts the generation of electricity on large scale by any other agency in the Valley. These provisions of the Act virtually confer the DVC with the task of large scale generation of power, and its distribution in bulk leaving the retail distribution in the hands of the distributing licencees and State agencies.

System Demand at the end of 2nd Five Year Plan on DVC System is detailed below :—

(*i*) *Distributing Licencees* :	124,000 kW of which West Bengal accounts for 108,000 kW.
(*ii*) *State Govts* :	147,000 kW of which West Bengal accounts for 27,000 kW.
(*iii*) *Large Industries* :	
Iron & Steel	133,000 kW of which West Bengal accounts for 52,000 kW.
Others	42,000 kW of which West Bengal accounts for 8,000 kW.
(*iv*) *Rly. Traction*	116,000 kW of which West Bengal accounts for 50,000 kW.
System Demand (with diversity factor) :	489,000 kW of which West Bengal accounts for 212,000 kW.

The demand on account of West Bengal includes the following :

(*a*) Schemes of the West Bengal State Electricity Board at Burdwan, Kharagpur, Pandaveswar (Ranigunj Coal-field area) and Bandel ;

(*b*) Comparatively smaller consumers
(*i*) Dishergarh Power Supply Co. Ltd. ;
(*ii*) Associated Power Co. Ltd. ;
(*iii*) Chittaranjan Locomotive Works, Chittaranjan ;
(*iv*) Hindusthan Cables, Rupnarainpur ;

(*c*) Large consumers
(*i*) Calcutta Electric Supply Corporation Ltd. ;
(*ii*) Indian Iron & Steel Co. Ltd., Burnpur & Kulti Works and
(*iii*) Steel Plant at Durgapur ;

(*b*) Rly Electrification schemes for Howrah-Burdwan, Burdwan Asansol and Howrah-Kharagpur Sections.

Distributors of DVC Power

Distributing Licencees :

There are two licencees namely Dishergarh Power Supply Co.Ltd. & Associated Power Supply Co.Ltd., operating in the Raniganj Coal-field areas. These Licencees have some serviceable plants. These have grown old and are incapable taking any further load. Augmentation of power supply position in this area was, therefore, necessary for further development. These licencees took supply from the DVC as soon as it was available for distribution to Collieries, Engineering Works, Fire Bricks & Refractory Works, Ice Factory, Glass Works, Cotton Mill, Bycycle Manufacturing Works etc., and a few small Distributors.

All categories of industries of West Bengal are mostly located in and around Calcutta. Calcutta Electric Supply Corporation supplies these industries in addition to the domestic requirement of the city and its suburbs. In view of the expansion schemes of the existing industries and development of new industries under the Second Five Year Plan

and also of the expansion of the Calcutta City and its suburbs on account of large influx of displaced persons, there is likely to be a shortage of power in the CESC's System in 1956-57. The Supply Corporation requested the DVC to supply them 40 MW of power initially progressively rising to 95 MW in about four years time and they have already entered into an agreement for it.

State Agency :

Electrification schemes of the West Bengal State Electricity Board costing about 4.25 crores were taken up and implemented under the First Five Year Plan to supply an additional area of 3,000 square miles.

Rs. 13 crores has been provided for electrification schemes of the W.B.S.E.B. under the 2nd Five Year Plan. Share of West Bengal towards the electrification schemes of the DVC for the installation of the Second Thermal Station at Durgapur, the fourth unit at Bokaro and the extension of transmission and distribution system accounts for about Rs. 6.12 crores leaving the balance of Rs. 6.79 crores approx. for other schemes.

State Electricity Board has planned to receive supply from the DVC at a number of points for retail distribution and these are at :

(*i*) *Pandaveswar* (*Raniganj Coal-field*)

25% of total coal-fields in West Bengal are electrified. It is proposed to undertake extensive electrification of this area to step up coal production as envisaged under the Second Five Year Plan. 4000 kW Mayurakshi Hydro-Electric Station of the State Government is proposed to be interconnected with the DVC System at this place to make up the deficit of demand for power in the areas to be supplied from Mayuraskhi during the dry period when the output of the hydro-electric station is restricted.

(*ii*) *Burdwan*

Burdwan Town was supplied with electricity by a private licencee. Due to unsatisfactory power supply position at Burdwan, the State Government took over the management from them to meet the potential demand of Burdwan Town, Golshi, Memari, Rasulpur and community development centre at Saktigarh by augmenting the supply position from the DVC System.

(*iii*) *Durgapur*

A 60,000 kW power station (comprising of two 30,000 kW unit) as an adjunct to the Coke Oven Project of the Government of West Bengal at Durgapur, which will be interconnected with the DVC System, has been planned mainly to supply a number of industries like Coke oven plant, Chemical Works Refractories, Sanitary Ware Works, Lift Irrigation scheme of Durgapur-Malda Section, military authorities at Panagarh, the towns of Bankura, Vishnupur and the rural areas enroute and bulk supply of 45 MW of power to the DVC. Power requirement of the Durgapur area will be met from the DVC System till the said thermal station starts functioning.

(*iv*) *Kharagpur*

The scheme envisages the distribution of power to Rly. Workshop at Kharagpur, Midnapur Town, Hijli Technical Institute, Kalaikunda Aerodrome, Ghatal, Garbeta, Chandrakona, Ramjibanpur, Arambag, Jhargram etc.

(*v*) *Bandel Area*

It is proposed to supply power to Messrs Gourepore Electric Supply Co. Ltd., to augment their resources and extend the transmission system to Rishra, Uttarpara and Belur to meet the power requirement of Messrs J. K. Steel Ltd., Hindusthan Motors, and National Iron & Steel Co. Ltd.,

Large Industries

The following large industrial establishments are located in West Bengal portion of the Damodar Valley and their power requirement will be met by the DVC.

(*i*) Chittaranjan Locomotive Works, Chittaranjan;
(*ii*) Indian Iron & Steel Co. Ltd., Kulti & Burnpur ;
(*iii*) Hindusthan Cables, Rupnarainpur and
(*iv*) Third State-owned Steel Plant at Durgapur.

One Steel Foundary at Chittaranjan Locomotive Works is proposed to be installed for which additional supply is needed. Indian Iron & Steel Co. Ltd., have got extensive scheme both for their Kulti and Burnpur Works to increase their production and works in this direction have already been taken up. The Iron & Steel Company has got some thermal power plants to meet the demand of the works. These plants have grown old and are incapable of taking additional load. Power supply for expansion scheme is, therefore, needed from the DVC.

Railway Electrification

Indian Railways have decided to electrify of the following Sections in West Bengal for which power will be supplied by the DVC:

(*i*) Howrah-Burdwan Section including Tarakeswar Branch ;
(*ii*) Burdwan-Asansol Section and
(*iii*) Howrah-Kharagpur Section.

The Corporation have already entered into contract with its consumers for supply of 245,150 kVA of power of which West Bengal accounts for 1,328,000 kVA. Other contracts are now under negotiation and expected to be finalized soon.

Operation

Large scale operation of DVC Power System could be said to have started from January, 1952 through portion of transmission and distribution System built initially prior to commissioning of the permanent arrangement for distribution of surplus 25.5 MW of power from the power station of Sindri Fertilizers & Chemicals Ltd., to relieve acute power shortage in the Jharia & Raniganj Coal-field areas.

A limited amount of power from the construction power plant of the Maithon Project was made available to the Chittaranjan Locomotive Works to meet their initial power requirement prior to commissioning of the DVC Grid to nurse the load.

The Corporation has to depend on foreign countries for supply of heavy electrical equipment. There was some delay in construction programme and commissioning schedule in initial stage for late delivery by the manufacturers. Works were completed as and when

the equipment were received and new consumers connected.

The first set at Bokaro Thermal Power Station and Tilaiya Hydro-Electric Station was commissioned in February, 1953. All the other sets of both the power stations were brought into commercial use from December, 1953.

Power System of the DVC is under operation for the last five years. The following consumers in West Bengal are now supplied with power.

(*i*) Dishergarh Power Supply Co. Ltd., at Dishergarh and Kumardhubi ;
(*ii*) Associated Power Co. Ltd., at Seebpur and Luchipur ;
(*iii*) West Bengal State Electricity Board at Pandaveswar, Durgapur and Burdwan ;
(*iv*) Indian Iron & Steel Co. Ltd., at Kulti and Burnpur ;
(*v*) Chittaranjan Locomotive Works at Chittaranjan and
(*vi*) Hindusthan Cables Ltd., Rupnarainpur.

Supply to Calcutta Electric Supply Corporation and the Eastern Rly. for electrification of Howrah-Burdwan Section at Howrah is expected soon.

The following table will indicate the extent of utilization of DVC power in West Bengal during last five years :

generation of the DVC and the State Government can hardly cope with the estimated demand at the end of the Second Five Year Plan.

In major countries planning for power production is kept well in advance of industrial development. 80% increase in electricity production is ordinarily provided for 60% increase in industrial production. Capital to the extent of Rs. 3,000/- to Rs. 5,000/- and one man will remain unremunerative and idle for shortage of each kW. Alternatively, one kW of surplus available capacity will mean about Rs. 1000/- to Rs 1,500/- of unremunerative investment with very little additional ill effect.

The State Agencies have entered into power supply business in large scale along with the private enterprise in the state in recent time. It behoves on the authorities to take necessary steps to augment the generating resources of this region in time to save the good name of public enterprise particularly in this region, which is highly industrialised.

A co-ordinated technically and economically sound plan keeping in view the stability and satisfactory operation of the systems already in operation in this region may be initiated right now to take care of the situation. All possible resources like water availability of Kangsabati Project, new found coal-reserve in Bankura areas, hydro-electric resources in the Northern part of the State and all the resources of Damodar Valley and the proposed experimental atomic power

Progress of Sale in West Bengal

	Distributing Licencees.		*State Govt.*		*Large Industries*				*TOTAL*	
					Iron & Steel		*Others*			
	kWh (mil)	*Rev. Rs. (L)*	*kWh (mil)*	*Rev. Rs. (L)*	*kWh (mil)*	*Rev. Rs. (L)*	*kWh (mil)*	*Rev. Rs. (L)*	*kWh (mil)*	*Rev. Rs. (L)*
1952	26.719	14.409	—	—	9.368	4.537	7.762	292.4	43.849	23.238
1953	37.080	19.919	—	—	19.764	9.148	9.740	2.289	66.584	34.356
1954	52.441	26.470	0.495	0.312	21.940	9.849	12.590	6.774	87.466	43.405
1955	55.278	27.134	1.749	0.974	41.979	18.529	14.810	7.535	113.816	54.172
1956	69.290	33.561	7.215	3.921	69.267	31.512	15.755	8.087	161.527	77.081

Conclusion

The available firm capacities of the existing installations when added with the new schemes for power station in coastal areas of this region may be kept in view while planning a co-ordinated power system for the region.

Subject V

Problems & Prospects of Drainage

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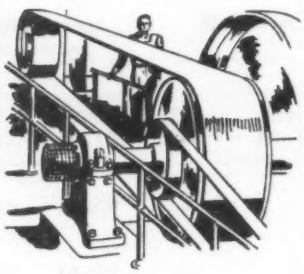

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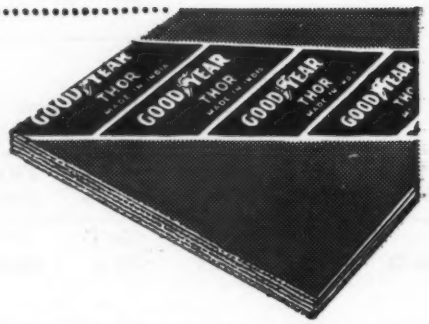

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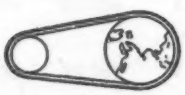

GOODYEAR

INDUSTRIAL PRODUCTS DEPARTMENT

THE GREATEST NAME IN RUBBER

Sundarbans, its Problems and Possibilities

By A. C. GUPTA

THE name Sundarban is composed of two words—*Sundri*, a timber yielding mangrove of commercial importance botanically known as Heritiera minor, and *Ban* meaning a forest.

The Sundarban proper is an enormous-sized delta of about 8000 sq. miles in extent distributed in two districts, viz., the 24 Parganas (3000 sq. miles approx.) of West Bengal, and Khulna (5000 sq. miles approx.) of East Pakistan. The Ganges and the Brahmaputra, the two outstanding rivers which drain the Central and the Eastern Himalayas together with a large number of their lesser associates have for ages carried down vast quantities of silt and deposited the finer alluvium at their mouths near the sea thus giving birth to this enormous tidal swamp.

Geography

The Sundarbans proper is bounded on the west by the Bhagirathi (also known as the Hughli), on the south by the Bay of Bengal, on the east by the Baleswar which separates the districts of Khulna and Barisal in East Pakistan and on the north by the Dampier-Hodges line. While on the west the Sundarbans ends abruptly at the Bhagirathi on the east it is connected to Burma by a narrow interrupted strip of tidal swamp running through the coast of Barisal, Noakhali and Chittagong variously known in the different localities as the Barisal Sundarban, the Chakaria Sundarban, the Mahiskhali Para etc. On the west beyond the Bhagirathi the underlying rock is alluvial ferralite (laterite) derived from basic volcanic rocks, and on the east at Chittagong the principal rocks are ferralite and shale of tertiary formation. The composition of the crust in and on the two flanks of the Sundarbans suggests that sometime in the dim past very large volumes of water drained out of the Central and Eastern Himalayas more or less converged on the north of the former undivided Bengal and descended to the sea through a comparatively narrow strip of land with a terrific velocity tearing out all the rocks that fell on its way, carrying the same to the sea and thus initiating the formation of the shallow continental shelf of the bay. It seems also that this great sheet of onrushing water from a large stretch of the Himalayas shifted its small bunch of channels sometimes to the east and sometimes to the west through a coastal area delimited by the Baleswar and the Bhagirathi on either side, and that this process went on over a very long number of years in course of which the small number of original channels with very large volumes of water descending through them often changed their course leaving moribund water courses on the discarded sites and gradually forming a very wide flood plane. The eventual result was the appearance of a large number of channels the majority of which had very small discharge in comparison with the width of their beds. The area being subject to tidal action a back rush of the silt from the bay occurred, and the silt which was previously carried down and pushed into the bay now started entering the moribund channels from the bay and being deposited inland. The channel bed thus became steadily raised, numerous islands were formed due to a lack of uniformity in the process of siltation, and eventually a number of narrower channels appeared connected with one another by a network of creeks or spillways. Depending on a steady increase or decrease of the headwater supply the process of siltation continues in a forward or reverse direction and sadly enough it is progressing in the reverse dierction in that portion of the Sundarbans that now lies within the State of West Bengal, and besides it is more active on the west than in the east. The final phase of such siltation is the formation of a maritime swamp surcharged with salt, and owing to the land having risen immediately above the tide level the position is static. It is only at tidal bores or during cyclones or similar occasions that salt water from the channels and the creeks finds ingress into the swamps, but such occasions are few and far between and practically no further rise in the ground level results.

Historical Background

Originally the whole of the Sundarbans was an uninhabited waste, and in the early part of the British rule it was once described as the pestilential tract which afforded a home for wild animals and shelter to smugglers and pirates. The vicissitudes of fortune of the country lying on its north and on its west resulting from the clash of Moghuls and the Pathans, the Khatriyas and the Mallas, the original inhabitants of the land, and latterly the annual raiding by the Borgis (Mahrattas) under the leadership of Bhaskar Pundit make the history of the past dim and fragmentary. The 14th century A. D. seems however to be a

historical landmark for the tract, and it was then or thereabouts that the main flow of the Ganges changed over to the Padma from the Bhagirathi by gradual stages. The Bhagirathi having been a large and active river uptil then prosperity reigned on its and on the banks of its numerous branches, and and the prosperity gradually waned as the river system grew moribund. Tamralipta, as the present day Tamluk was then called, was a prosperous town on the bank of the Bhagirathi. A little later, and perhaps in the 15th century A. D. when the Malla chieftains at Bishnupur (Bankura) attained the peak of their power large parties of the Mallas started migrating eastward, and some of them crossed over to the western Sundarbans, made large clearings in the mangrove forest and started cultivation after putting up embankments to keep out the tide water. It was thus that a part of the Sundarbans on the west of the Matla was gradually shorn of its forest and brought under cultivation, and it was this area in particular that suffered the most from the depredations of the Mugh and the Portuguese pirates. It Emperor Shahjehan who in the middle of the 17th century first took upon himself the task of checking the of the pirates, and he put up a garrison on the right bank Bhagirathi at a small township called Hijli, which had meanwhile been established by one Taj Khan towards the end of the 16th century. Although the presence of the garrison at Hijli gave a certain measure of protection to Tamralipta and other small townships higher up the river it produced no effect in the reclaimed parts of the Sundarbans on the east of the Bhagirathi where the pirates now intensified their operations. Many settlers were ruined, and an atmosphere of utter insecurity having prevailed, others abandoned their holdings, moved further north where the raids of the pirates were less frequent and the water less brackish, and made new settlements there after clearing more mangrove forest. Security gradually prevailed with the advent and the establishment of the East India Company at Calcutta in the 17th century, and the population as a result grew and spread farther afield, The feritility of the land, and the abundance of fish and game drove the colonists to face many hazards and they continued to penetrate both from the north and the west, but mainly from the north. In the 19th century after the British Govt. had taken over power from the East India Company a policy was framed to encourage the reclamation of waste lands in the Sundarbans in all possible ways, and this policy eventually led to the promulgation of the Waste Land Rules of 1853 which was calculated to encourage big landlords to invest money for the reclamation of waste lands, which was not likely to yield a return for some years. These Rules which provided for a 99-year lease and for unlimited grants merely attracted a large number of land speculators, but failed in its object of reclamation. In 1879 these were therefore discarded and replaced with the Large Capitalist Rules, and the Small Capitalist Rules. The former provided for a 40-year lease and for a maximum grant of 5000 bighas, while the latter provided for a 30-year lease and for a maximum grant of 200 bighas. It was gradually realised that a great shortcoming of the Large Capitalist Rules lay in the fact that these made no provision for the maintenance of the embankments by the lessee after he had put these up and the tenants to whom such maintenance was vital were thus exposed to a great risk. There being other defects also, the Government of Bengal appointed a committee of leading revenue officers to investigate the whole position. The Committee in their report published in Decebmer, 1903, emphasized that it was essential to abolish the system of leases to capitalists and to proceed by direct settlement with the actual cultivator, and they recommended that Government should undertake the cost of making exterior embankments, and of effecting developmental works on the land. The Board of Revenue accepted the recommendations in toto and decided to apply these to the areas still available for reclamation. A notification was accordingly issued in November, 1904 suspending the operation of the Capitalist Rules of 1879, and in 1905 on the eve of the partition of Bengal rules under the notification were framed and issued for application to the 24 Parganas Sundarbans, and it was also in the same year that the post of the Commissioner of the Sundarbans was abolished.

Constitution of Reserved and Protected Forests

In 1874 Sir Richard Temple, the Lieutenant Governor of Bengal, made a declaration of his policy in regard to the Sundarbans in course of which he laid down that the area was to be preserved in its virgin state, that it was to be used as a source of timber and firewood, and he opined that its reclamation was not justified except to a very limited extent. This policy resulted in the constitution of Reserved and Protected Forests, and the boundaries of such forests were fully defined by 1877. In the subsequent years government decided to maintain these state forests till the tidal spill had built up the land and raised it to such an extent that it could be cultivated in the ordinary course without being protected by high embankments. It was recognized that such forests provided a measure of protection against the inroads of the sea into areas that had already been reclaimed and it was believed that premature reclamation with marginal embankments resulted in raising the bed of the river above that of the reclaimed lands, which thus became liable to inundation whenever the embankment was breached. The river water being saline an inundation rendered the land unfit for cultivation for several years. It was made a rule that whenever there was a proposal for the settlement of a new area the Irrigation and the Forest Departments were to be consulted. In the early part of the present century the last of the Protected Forests was relegated to cultivation. At the time of partition of Bengal in 1947 the area of Reserved Forest in the 24 Parganas Sundarbans was approximately 1600 sq. miles, but the growing pressure of population has since succeeded in getting a part of this area released for cultivation.

Imprudence of Man

Blunders were made in the haste of reclamation, and the foremost of these was the premature reclamation of the mud banks in the process of growth vertically. The spill of high tide was shut out with mud embankments, and in consequence no siltation occurred and no further growth resulted. In a large number of cases however the mud banks had come near maturity and reached a stage where the rate of vertical growth, were it allowed to take place, would have been very small indeed. This is due to the reason that such mud banks get the spill at spring tides only, and even then the depth of the spill is very small. The putting up of embankments on or very near the margin constituted the second blunder, and

such embankments which had to bear the full fury of wind-driven waves proved unequal to the strain and often gave way.

Present Position Untenable

The status quo cannot be maintained for reasons more than one, and something different has to be created out of what we have in the 3000 sq. miles of the 24 Parganas Sundarban. About 2200 linear miles of mud embankment now surround about 1300 sq. miles of cultivation, and a fair proportion of the enclosed area is thrown out of cultivation almost each year due to breaches and consequent ingress of salt water. Apart from the very high cost involved the actual maintenance of the embankment is very difficult owing to its stupendous length, and in the event of a few breaches occurring in any year the cost of of sealing, dewatering and sweetening the inundated fields, and provision of relief measures will push up the annual cost of maintenance to astronomical figures. Besides, due to rapid siltation the beds of the rivers and of the spillways are rising at an alarming rate, and navigation is becoming increasingly difficult.

Choosing a Remedy

In the circumstances one may reasonably ask what is the remedy, and we shall now proceed to consider the possible remedies one by one. Before we do so however it will be convenient to take account of certain salient facts on which our considerations will have to be based for any decisions made without these will be either unsound or unproductive of the maximum good. Firstly, the small state of West Bengal with the highest density of population in India (841 per sq. mile against 312 of India) is still having an influx of refugees from East Pakistan, and consequently it will not be feasible to uproot the existing population on any scale from anywhere and rehabilitate them elsewhere even for a number of years. Secondly there is hardly any prospect of effecting an increase of the shrunken headwater supply of the Sundarbans rivers. Thirdly, the delta as a whole has not yet reached the static climax stage which is a maritime swamp, is still in the process of growth, and the force of growth can be harnessed to produce effects suitable to our requirements. Fourthly, the rivers and the creeks in the western part of the 24 Parganas Sundarbans are silting up much faster than those in the eastern part, and Calcutta being a major port on the extreme west the position is getting serious.

What is the remedy sought and what is the objective? The feeling of insecurity of the cultivator and of the colonist must be removed by taking adequate measures to prevent breaches of the protective marginal embankments which occur annually and are sometimes extensive, and the expenditure on maintenance must be kept within reasonable bounds on a long term basis. On an honest computation of the cost being made, and the enormous sums spent on providing relief, resealing the breached embankments and reclaiming the flooded fields being taken into account the present level of cost would appear to be excessive while the remedy is only temporary and very localized. Siltation must be controlled and regulated, and the more or less uniform rise of the beds of the watercourses checked so that navigation continues to be possible, and a part of those lands that were enclosed within embankments too prematurely and forced under cultivation must be released to nature and allowed to grow upward a little more.

Our fault has been that we have been continuing an unscientific system which originated a few centuries ago, and was practised only on a very small scale. It has since become extensive, and is still growing while the position has worsened by a steady shrinkage of the headwater supply.

There are only two bases on which a possible remedy may be considered. One is on the basis of an assumption that the tide carrying its silt charge will continue to flow inland while the other will presuppose that the months of all the rivers will be sealed and the sea shut out. Of the latter possibility a short and very preliminary investigation was made in 1954 by a small party of technicians of which the author happened to be one, and the Dutch method of poldering was considered. The figure of estimated cost was almost astronomical, and it was mainly on that account that the matter was not pursued farther. Since the method of poldering is still being advocated in certain quarters though rather half heartedly, it is necessary to consider all aspects of the method from the point of view of its applicability under our conditions. This method was designed as a last resort for the reclamation of a delta on the coast of Holland which had grown to the climax stage, and had developed into a static maritime swamp more or less of the same type as the area known as the salt lake in the neighbourhood of Calcutta. The spillways having filled up no drainage was possible, and the banks of the former spillways which caught a comparatively larger quantity of silt being higher the interior remained water bound and surcharged with salt. The conditions in the Sundarbans proper are however otherwise as have been stated earlier, and a difference in level exists between the low tide and even the prematurely reclaimed lands so that drainage through sluice gates and with it the leaching out of the salt in the earth are possible. There is therefore no case for resorting to poldering in the Dutch manner. Then there is the point of climate. Holland being a cold country is comparatively much safer from the malaria-carrying mosquitoes and other dreaded insects for which the large volumes of stagnant water in the poldered areas may provide a flourishing condition. Perhaps the greatest danger potential of poldering is the possibility of a large quantity of silt getting into the Bhagirathi in consequence, and being deposited there making the present bad condition still worse. The port of Calcutta being involved, the risk is perhaps too big to take.

In the circumstances the best course would perhaps be to let the tide flow inland, but at the same time to control and regulate the manner of siltation with the object of maintaining the depth of the channels at the expense of their width and prolonging the life of the waterways as far as possible. If the supply of headwater does not improve it is possible that all the waterways will fill up at some distant date, but if the correct line of action is pursued there will be no maritime swamps at the end.

Rise of Bed and its Effects

The portion of the Sundarbans lying to the west of the Matla river has suffered most from siltation

and the consequent rise of the beds of the waterways, and the Saptamukhi provides a fine example of such happening. The greater part of this portion of the Sundarbans was prematurely reclaimed many years ago right up to the seaface. Under natural circumstances the silt-laden flow tide would have spilled over a very large area covered with vegetation, and then withdrawn through the spillways leaving a great deal of its charge on the forested land, but the ways being now barred by embankments much of the silt is perforce deposited on the beds of the waterways, the intensity of siltation at any one point being determined by any resistance that may retard the flow at that point. The resultant channel in a river or creek is thus very twisted and navigation proves exceedingly difficult and often perilous especially at the end of a flow tide when the course of the channel remains invisible, and the level of water begins to fall. This is most vital for the Sundarbans which provides a passage for millions of tons of waterborne cargo each year between Assam and East Pakistan on the one side and the port of Calcutta on the other. The steady rise of the beds of the watercourses is also gradually exposing the low-lying reclaimed areas to an increasing degree of risk of inundation by raising the level of the river water at high tides. It is not the tide that rises higher and the rise results from the down-flowing river water being opposed by a rising tide on an elevated river bed.

Application of the Principles

Although it would be technically correct to remove the embankments from all the reclaimed areas that are below the high water level at nip tide it would not be practicable to do so in view of the pressure of population in which respect West Bengal ranks the highest in India. But at the same time it has to be borne in mind that many plots were very prematurely reclaimed and that with the elevation of the beds of watercourses the risk of inundation is rising. This is not a mere apprehension, for each year there are breaches, inundations, newspaper headlines, relief measures, rehabilitation and an enormous expense. A via media has obviously to be struck and it will be a happy day when the government and the people will see their way and agree to resume by batches the low-lying plots, especially those nearer to the seaface so that these may be restored to nature for a number of years for a vertical growth of land. Research will be needed to determine how long nature will take to do her work, and if she will need any aiding. It is probable that aiding by means of afforestation will hasten the process of land buliding but if such afforestation is ever undertaken. two points must be borne in mind, viz.,

(*i*) Afforestation of a tidal swamp is a very specialized technique, and anyone practising it must possess both knowledge and experience.

(*ii*) The type of afforestation to be undertaken is to be matched to the objective, and to nothing else.

In regard to the rehabilitation of the uprooted population, there should be no more difficulties after the first batch of plots have been resumed, for the second batch will not be taken up until the first batch is ready for reclamation, and the population dislodged from the second batch of plots may be rehabilitated on the first. Such line of action would help in other ways also. The protective measures as obtain at present were mostly ill-planned, and are therefore unsatisfactory. The marginal embankments are often too close to the river, and there being nothing in front to curb the fury of storm waves, these frequently collapse. It is essential that there should be a marginal strip between the river and the embankment and that this strip should have a forest cover. The width of the strip should normally be about 100 yds, but it should vary and it should depend on the situation in each case. If this were done, the embankment iteslf would serve only as a second line of defence, and the need for the constant retirement of embankments would very nearly disappear. A certain amount of research is necessary in this respect also. Embankments fringed with a belt of forest usually develop crab holes, and crab holes are not conducive to the well being of a protective embankment. Ways have to be discovered to eliminate the crabs, and a way the author can suggest on an experimental scale is the introduction of a species of carnivous brown monkey which inhabits the tidal swamps in the Arakan (Burma). These monkeys subsist on crabs and some 20 years ago the author used to watch them pull the large crabs out of their holes with great dexterity. There would be no difficulties in putting up in putting up embankments on the correct lines if plots were resumed by government in convenient sized batches.

As regards the control and regulation of the process of siltation which must go on, it is very difficult to say without the preliminary of a research carried out under our conditions which method or methods would succeed best. The permeable screen has been suggested in certain quarters, but considering that a method, whatever that may be, will have to be given an extensive application over a very large area it is desirable that some easier and a more inexpensive method is devised more or less on the principle of the permeable screen.

Production Potential

The Sundarbans soil is fine alluvium of considerable depth; and is very fertile, but its possibilities have so far been considerably restricted by salt which is brought in by the tide, and is sprayed by the waves and the wind. The elimination of salt from cultivation to the maximum possible extent and by all possible means is necessary to ensure the cultivation of certain essential crops like jute, and to secure a much higher yield of paddy which is in cultivation at present. It is confidently hoped that this circumstance would be achieved if the ingress of salt water into cultivation were completely stopped, if the salt in the fields were more effectively leached out by providing more efficient inland drainage, and if the salt sprays were held back by providing shelter belts of trees like Calophyllum inophyllum within the enclosed area. If the cultivation of the better quality of Jute crop could be secured in this area, not only that a great deal of our worries to find the raw material for our factories would end, but also a considerable saving of foreign exchange would result.

Flourishing Sundarbans

By K. B. RAY

THE Sundarbans in West Bengal have an area of 3,000 sq. miles (Fig. 1). In his book 'Good Old Days of John Company, 1882' W.H. Carey writes :

"The Sundarbans to the south of Calcutt .... were once a fertile land covered with cities and full of life. ....Conti, the Venetian traveller, about 1450, came to the mouth of the Ganges, and writes that the banks were covered with beautiful cities and gardens. In 1616, the King of Arracan devastated the lower districts of Bengal, carrying away the inhabitants to slavery. Bolts, in his 'India Affairs', states that the Sundarbans were abandoned about 1620 by their inhabitants in consequence of the ravages of the Mugs".

Reclamation during British Rule

With depopulation, maintenance of bunds came to be neglected. There were breaches of bunds and submergence of land under saline water. W. H. Carey writes :

"The first attempt, on the part of the East India Company to cultivate the Sundarbans, was made in 1790-91, through Mr. Tilman Hinckell, who was appointed Superintendent of the Sundarbans..... Several grants were made to individuals and some progress made, but the plans resulted in failure".

Later on, reclamation of the Sundarbans was again taken up and at present 2201 miles of bunds protect 750,000 acres or about 1172 sq. miles of cultivated and inhabited lands. In the balance 1828 sq. miles, there are no bunds.

The reclaimed lands are not, however, in a good condition. Before the abolition of the zemindari system, each landlord was expected to maintain the bunds in his land. Numerous and frequent breaches occurred in the bunds each year. Saline water entered through a breach and suddenly submerged the land. Mud huts in villages collapsed. All crops and food stocks perished. The million inhabitants are thus poverty stricken.

Sundarbans in Free India

In the Statesman, Calcutta, August 30, 1956, it is stated that the Sundarbans have always "been a chronically deficit area, requiring relief to an annual extent of about Rs. 20 lakhs; nor has zemindari abolition as yet altered this condition, while some of a landlord's duties, such as maintaining bunds are alleged to have been little better performed by the Government, though Rs. 38 lakhs were devoted to this purpose last year and Rs. 37 lakhs budgetted this year." On August 25, 1956, "shortage of funds, it is stated, is one of the main handicap of the Government. The revenue from the area amounts to Rs. 25 lakhs a year, while the cost of maintaining the embankments exceeds Rs. 1 crore".

Large areas, out of the 750,000 acres, at present remain submerged under saline water. One of the causes of this condition appears to be a prejudice against reclamation of delta lands. In the Statesman, August 26, 1956, it has been stated :

"Specialists in the Ganga Delta have unanimously advised against reclamation in the Sundarbans on grounds of its limitations and the serious repercussions it would have on the future of the country as a whole."

Reclamation in Holland

Reclamation of delta lands has not, however, caused any serious repercussions on the future of Holland, although it "consists almost entirely of the delta of the Rhine and Meuse, with low coast lands to the North" (Fig. 2).

In the Zuider Zee Works, published by the Netherlands Government Information Service, it is stated :

"One-fifth of the land area of the Netherland (12,850 sq. miles) lies below average sea level and more than half of the country (6603 miles) would be subject to flooding, if no dunes, sea and river dykes protected this area..... As far back as in the 13th century, the inhabitants of Holland started reclaiming and draining the land. Since that time, 2200 sq. miles have been reclaimed."

Inspite of such extensive reclamation, started about 600 years ago, the health and prosperity of Holland has not at all deteriorated. The rivers are in a good condition. Even sea-going ships ply on them for hundreds of miles.

High Cost of Maintenance of Bunds

The high cost of maintenance of bunds in the Sundarbans is one of the causes of shortage of funds. For example, a breach in the Kulgachi Bund along the Haroa River 30 miles east of Calcutta in August 1953 submerged 20 sq. miles of reclaimed land (Fig. 3). Work was taken up in September. Sal bullah piles were driven and earthfilled gunny bags dumped in the nullah of the breached bund. A Ring Bund 3 miles long and a shorter one near the breach were made. Seven large country boats, loaded with earth-filled gunny bags, were sunk in the nullah. The breach was closed; but a high tide came and the bund was again breached. The expenditure was about a lakh of rupees.

In November 1954, there was another attempt. Sal bullah and bamboo piles were again driven. Earth-filled gunny bags were again dumped. Ring Bunds were again made. The breach was closed in March 1955. The cost was Rs. 7 lakhs.

With over Rs. 7 lakhs, as cost of one breach repair, no wonder annual maintenance of bunds has been estimated by the Government at Rs. 1 crore.

Utilisation of the Mighty Force of a River

Many railway bridges exist over the torrential rivers below the foot-hills of the Himalayas, the mighty alluvial rivers in the plains, and the tidal rivers, in Eastern India. A Railway Engineer has many an opportunity to study river control at these bridges. There are also the rail-steamer transhipment ghat stations on the big rivers, which with the silting up of the deep channel along a river bank have to be shifted periodically. A Railway Engineer has on many occassions observed that with an increase in the velocity of a current of water, a channel is deepened by erosion of bed and banks; or with a decrease in velocity, a deep channel becomes filled up with deposit of silt. He is thus able to realise that a river has at its command a mighty force—its current of water.

Thwarting a river, by placing an obstruction across its current of water, such as a spur, creates eddies, which downscour the river bed, into which the materials forming the obstruction sink in and disappear. On the other hand, a current of water may be gently guided by suitably designed structures, their upstream end being placed in the channel parallel to the current of water in that region, ensuring thereby smooth, stream-line flow.

Bandals

To assist a river in the utilisation of the mighty force of its current of water, steamer companies in Eastern India use 'bandals.' These consist essentially of a series of pairs of lines of vertical bamboos, each pair of lines converging downstream (Fig. 4). Each bamboo is driven 3 or 4 feet into the channel bed. There is a slight decrease in the velocity of a current of water between the line of 'bandals' and the river bank, causing deposit of silt and rise in level of the channel bed. The consequent decrease in the sectional area in this part of the channel, causes more water to flow between the series of pairs of 'bandals' with increased velocity, which causes scour and deepening of channel. A greater depth is thus provided between the series of pairs of 'bandals' for navigation.

Permeable Screens

With a rise in water level in a river and consequent greater velocity, there is greater downscour of channel bed, so that the bamboos of the 'bandals' are undermined and topple over. An improvement in the 'bandals' thus became necessary and 'permeable screens' were evolved. These retain their position on the channel bed, even with a rise in water level and increased velocity of a current of water.

A unit of 'permeable screen' consists essentially of a wedgeshaped structure, with a wide rectangular base, the ends being triangles, the front and back being parallelograms (Fig. 5). The units shown in the photograph, is constructed with bamboos. Four weights at the four corners of the base of each unit, keep the structure in position on the channel bed against a strong current of water.

'Permeable screens' work on the same principle as 'bandals,' assisting a wide and shallow river to form new parallel river banks, having in between a narrow and deep channel.

Economical Maintenance of 2201 Mills of Bunds

For repairs to a breached bund, a line of units of 'permeable screens' laid on the channel bed along the river bank to proper alignment, ensures smooth flow and prevents creation of eddies. For this, the straights in the alignment must be joined by 'transition' curves (Fig. 6). The decreased velocity of a current of water, between the line of 'screens' and the river bank causes deposit of a part of its silt load creating a new river bank, which closes the channel formed through the breached bund. By the use of a line of 'permeable screens', the cost of repairs to a breached bund similar to that at Kulgachi will be within Rs. 1 lakh, as against Rs. 7 lakhs spent in 1953-1955.

Similarly in the other breaches, in the 2201 miles of bunds protecting 750,000 acres in the 1172 sq. miles of the Sundarbans, instead of sal-bullah or bamboo pilings, dumping of earth-filled gunny bags, sinking of loaded country boats, making of ring bunds, etc., if lines of 'permeable screens' are used, the annual cost of Rs. 1 crore as estimated for maintenance of bunds may be reduced to about Rs. 14 lakhs. This is within the revenue of Rs. 25 lakhs from the Sundarbans.

Reclamation of the Balance 1828 Sq. Miles

Of the balance 1828 sq. miles of the Sundarbans, at least 1000 sq. miles or 640,000 acres could be reclaimed. For this the many wide and shallow channels have to be narrowed, deepened, canalised and stabilised by a series of pairs of 'permeable screens'. Bunds are then to be made on the newly formed parallel river banks, having at intervals temporary sluices made of planks for the drainage of water from the reclaimed land. The salt in the land will be dissolved and drained away by rain water in about two rainy seasons, making it fit for cultivation. Owing to the deposit of fine silt for hundreds of years, the reclaimed land will be very fertile.

Paddy, vegetables and other crops will grow in great abundance on the reclaimed land. On comparatively higher parts of the land, houses with mud walls and corrugated iron roofs could be built for the

[*Continued on page* 98.

WEST BENGAL, EAST PAKISTAN AND HOLLAND

MILES 10 0 10 20 30 40 MILES

FIG. 1

WEST BENGAL

SUNDARBANS

HOOGHLY

CALCUTTA

EAST PAKISTAN

RUPNARAYAN

CANNING

HOOGHLY

MATLA

ROYMANGAL

BAY OF BENGAL

FIG. 2

HOLLAND

NORTH SEA

RHINE

MEUSE

LEK

RHINE

WAAL

MEUSE

HOLLAND

SCHELDE

SCHELDE

BELGIUM

RECLAIMED LAND

FIG. 3. AREA SUBMERGED THROUGH KULGACHI BREACH

JANARDANPUR

NAZARNAGAR

CHANDIHAT

HARIPUR

20 Sq. MILES SUBMERGED LAND

RING BUND

KULGACHI

NORTH KASIPUR

KULGACHI BREACH

MEHERPUR

BUND

BUND

HARODA RIVER

FIG. 4

'BANDALS' IN A RIVER

ERODING BANK

SAND BANK IN THE DRY SEASON

AA, BB SERIES OF PAIRS OF 'BANDALS'

A

B

ERODING BANK

FIG. 5. 'PERMEABLE SCREENS'

FIG. 6

REPAIRS TO KULGACHI BUND

ABC - 'PERMEABLE SCREENS'

RING BUND

BUND

BUND BREACH

BUND

HARODA RIVER

A

B

C

WEST BENGAL, EAST PAKISTAN AND HOLLAND
MILES 10 0 10 20 30 40 MILES
FIG. 1
WEST BENGAL
SUNDARBANS
CALCUTTA
HOOGHLY
EAST PAKISTAN
FIG. 2
HOLLAND
NORTH
SEA
RHINE
MEUSE
HOLLAND
BELGIUM
FIG. 3
AREA SUBMERGED THROUGH KULGACHI BREACH
JANARDANPUR
NAZARNAGAR
CHANDIHAT
HARIPUR
59 MILES SUBMERGED LAND
KULGACHI
NORTH KASIPUR
MEHERPUR
KULGACHI BREACH
BUND
SUND
FIG. 4
"BANDALS" IN A RIVER
ERODING BANK
SAND BANK IN THE DRY SEASON
AA, BB SERIES OF PAIRS OF "BANDALS"
A
B
ERODING BANK
FIG. 5. "PERMEABLE SCREENS"
FIG. 6
REPAIRS TO KULGACHI BUND
"BANDALS" - PERMEABLE SCREENS
BUND
RING BUND
BREACH
HARDA RIVER
MADE IN AUSTRIA
MADE IN AUSTRIA

Tidal Rivers of Bengal and the Problem of their maintenance

By N. K. BOSE,
P. B. RAY and G. SINHA

IN West Bengal tides and tidal rivers play a very important part. The whole of lower Bengal has been built up by the enormous quantity of silt brought down every year during the monsoon, by the Ganga and Brahmaputra river systems that drain almost the entire countryside north of the Deccan plateau. When these rivers come in contact with the saline tidal water from the Bay of Bengal, their courses become very unstable, the current is checked and the velocity drops down. The silt thus carried by them in suspension or in rolling is deposited at the seaface. This process of transportation of silt from the upper region during floods and deposition of the same at the seaface goes on for years and years and the deposited silt raises the level of the bottom slowly and gradually with ultimate formation of land at the head of the delta. With the formation of land the old courses of these rivers gradually become ineffective and new diverging branches are developed enclosing and intersecting the land already built, so as to raise it more quickly and to extend it towards the sea. This is in short the history of the formation of Gangetic delta.

This silt at the seaface deposited by the upland flood carriers remain mostly in an unconsolidated stage. During the tides which flow up the tidal rivers and creeks with strong velocity twice daily throughout the year this silt is picked up almost to the saturation point and carried inland. Due to the funnel shape of the Bay of Bengal the range of tidal rivers and creeks of Bengal are abnormally high. This has helped very much in raising the delta, infact raising it higher than what it would have been if the range was lower. But due to this high tidal range more and more of the unconsolidated silt deposited by the flood carriers is dispersed along the delta face to be picked up by the tides travelling inland through innumerable tidal channels. As a result of which less and less quantity of silt has actually been deposited in a consolidated state to extend the delta.

It would be clear from what has been said above that thousands and thousands of tons of silt carried from the Himalayas and upper India by the Ganga and Brahmaputra river systems are really responsible for the formation of the Gangetic delta, but this silt is also equally responsible for all the troubles that are being faced within the tidal channels and creeks of Bengal.

So long as the country side on both banks of these tidal channels are low, the river is free to spill, and during the flood tide the silt laden water spills over both the banks and the silt is deposited on low areas during the high water slack. During the ebb tide the spilled water comes back into the river free of silt, scours the river bed and keeps the river alive. So long as the levels of the countryside area are below high water level, these lands are not ready for reclamation. If however, these lands are reclaimed earlier, they will remain low for ever and natural drainage will be hampered. Moreover for this premature reclamation embankments are put on both banks to check saline tidal inflow, all spills to the river are closed and the silt brought in by the flow tide is deposited on the river bed. If at the same time the river does not get any perennial upland supply the silt deposited on the riverbed is not scoured the bed rises slowly and the river begins to deteriorate. Once the deterioration starts, the river becomes inactive within a very short time.

The usual ways by which a decaying tidal channel may be revived and maintained are (*i*) by supplying upland fresh water throughout the year for flushing the river bed, (*ii*) by free spill operation i.e. by throwing low lands open for free spilling, (*iii*) by local drainage. If requisite quantity of perennial upland water can be supplied through a tidal channel, the silt deposited on its bed will get scoured and the channel will remain in regime condition. But at present practically no upland water can be supplied, except during the monsoon season, to the tidal rivers and the possibility of flushing tidal channels by upland discharge is almost nil. A tidal channel can only be flushed by local drainage discharge during the drainage period and so it cannot keep a tidal channel in good condition throughout the whole year. Hence under the present state of affairs when no upland discharge can be supplied, tidal channels are to be maintained by free spill operation. But opening up a particular spill area at a particular point of the river will have its effect on a limited reach of the channel. A big spill area may have its bad effect too. Moreover one spill area will not serve the purpose for good as it will

ultimately get silted up and be ineffective. Hence it is very necessary to find out the exact spill areas with their extent, location and spacing so that the whole reach of the tidal river may be maintained in good condition.

Now introduction of any change in a tidal river for improvement will have its effect on the entire river system and in order to find out satisfactory remedial measures, the whole system should be carefully studied before and after the proposed modification. To carry out such studies in a tidal river system no cut and dry methods are available. The problem can be examined in a scale model or by mathematical computation.

PART I. TIDAL MODEL

The hydraulics of tidal rivers are very complicated, as such the operation of tidal models is more difficult than that of non-tidal models. However it is possible to use scale models for the solution of tidal rivers, and tidal models have been successfully used at different places. When the problem of navigation is involved tidal models are usually made of movable bed but when the question is of drainage and maintenance of the river in regime condition, the model can be made rigid and rigid bed models have been successfully operated in West Bengal for solving their problems. In this case the velocity of the river is the guiding factor for the study and an accurate knowledge of the flow and ebb velocity in the model at different phases of the tidal cycle before and after any modification is essential. It is the experience of Bengal engineers that an ebb velocity greater than 3 ft/sec. can scour and maintain the river in regime condition. Hence while conducting experiments attempts are made to increase the ebb velocity above this limit and that also for a sufficient duration of time. With this background the specific case of model experiments on Tolly's Nullah, a tidal creek of the river Hooghly has been described below.

Tolly's Nullah Model

Tolly's Nullah, is a small tidal creek of the river Hooghly, runs to the south of Calcutta and functions as a drainage channel and a boat route. All the drainage channels surrounding Calcutta are getting silted up with the result that drainage of these areas has become a serious problem. Tolly's Nullah is also suffering from the general problem of siltation. The condition of the Nullah above Tollygunj about 3½ miles from its outfall at Hastings, Kidderpore, is very bad. To reclaim the channel it has been proposed to excavate and dredge the Nullah in the upper reach and to put up a spill chamber, if necessary, at the head of the Nullah with a view to divert a part of the discharge laden with silt into the spill chamber so that the silt depositing in the river bed itself may be scoured by the silt free water coming out of the spill chamber during the ebb. For this purpose it is proposed to set up the spill chamber in the triangular piece of land between the railway line, Tolly's Nullah and Gariahat Road. The area is low and would be about 33 acres in extent (Fig. 1)

A model of Tolly's Nullah starting from its outfall at the Hooghly at Hastings to about half-a-mile beyond the point where the spill chamber is to be situated was constructed with a horizontal scale of 1 in 200 and a vertical scale of 1 in 40. With these scales, the velocity scale in model comes out to be 1 in 6.3, the discharge scale to be 1 in 50.400 and the time scale 1 in 23.5, i. e. one complete tidal cycle of 12 hours 25 mins. would be 23.5 minutes in model. In this model attempts were first made to generate the tide mechanically, generating machine based on pneumatic principles ; but, due to certain difficulties, the tides were ultimately generated mannually by the regulation of a sliding gate. For the construction of the model the bank survey of 1929 brought up-to-date in 1945 and the cross-sectional survey and gauge reading of 1945 were utilised.

As the model was required for studying the effect of the spill area on the regime of the river, the model was made rigid, and the length of the model was taken half a mile above the point where the spill area was to be taken off. In this connection it may be mentioned that the upper end of the Nullah loses itself in a *bil*, called the Samukpota *bil*, for which no detailed survey were available. Hence the upper portion of the Nullah could not actually be reproduced in the model and the usual model technique of representing the upper portion by means of a spill chamber in labyrinths was applied.

Proving of the Model

The first and formost part in experimenting with a tidal model is the proving of the model. To do this, the gauge curves for different tides at Kidderpore/ Tollygunj Stn., which is the nearest gauge site in the Nullah from the outfall, was correctly reproduced in the model by controlling the discharge entering into or coming out of the model by means of the operation of the sliding gate. But other gauges at Tollygunj or at Russa were not reproduced at all (Fig. 2). The spill chamber in labyrinths at the tail end was adjusted by changing the shape, length and total area but without any marked effect. At this stage the gauge readings at Tollygunj were found to be always higher in the model. At Russa it was mostly higher during the flow tide. Friction in the model bed was also lessened by smoothing it but no appreciable difference in the gauge curves was noticed. As all possible scoures which might introduce errors in the model have been checked it was thought necessary to investigate the correctness of the information of the permanent closure of the Chetla lock gate feeding the Chetla boat canal and situated at about 3½ miles above the Kidderpore outfall. From the model gauge curves it appeared that the lock was still in operation. Based on this information the Chetla lock gate was not operated in the model. The actual site was therefore inspected and it was noticed that the draw of water in the Chetla canal through the lock was quite appreciable and the information about the permanent closure of the lock was not correct. It was further learnt from the Commissioners for the Port of Calcutta that the lock gate had never been closed except for one or two occasions for repair work as the tidal water feeding the Chetla boat canal during the flow tide was pumped by them for their Dry Dock. This water was also never returned to the Nullah. When all these facts were taken into consideration and proper adjustments of the spill chamber in labyrinths at the tail end of the the Nullah was made. The Tollygunj and the Russa gauges were also correctly reproduced in the model (Fig. 3). For details, reference may be made to Bose and Ray[7] and Annual Report of River Research Institute, 1949[3]

Model Results

After the model was proved, experiments were conducted on it and different proposals were studied, one after another, until a satisfactory solution to the problem was obtained. The findings of studies in the model with different proposals are described below.

1. Under the existing condition the maximum ebb velocity in the upper reach of the Tolly's Nullah is below 3 ft/sec. in most of the sections. It was at best 2 ft/ sec. to 2.5 ft/ sec. (4) If the Chetla lock gate is closed and no water is drawn through Chetla boat canal, the velocities during ebb increases considerably in the upper reach except at a few points. With the introduction of a spill area of 33 acres at the proposed site, the duration of ebb velocity above 3 ft/ sec. was also improved. Thus this drawing of water by Port Commissioners for their dry dock has been found from the model as a major cause for deterioration of the reach above this drawing point on the Nullah. Presuming that this drawing operation would have to be continued for the Port of Calcutta, the drawing point was shifted further up by about a mile but no marked improvement on the ebb velocity in the upper reach was obtained.

2. The upper reach of the Tolly's Nullah above Chetla Lock was then excavated and dredged as proposed by the Canals Division, Irrigation & Waterways. The proposed enlargement of sections was done by cutting the banks without lowering the bed. The model showed that the resectioned reach would again silt up even if an area of 33 acres above Garia at the proposed site was opened for free spill operation of the Nullah. Even if this spill area was increased to 133 acres and 180 acres the proposed resectioning of the Nullah would not be successful. The magnitude of the ebb velocity in the upper reach of the Nullah was not much improved by any of these modifications. (4,6)

3. As the operation of the spill area under natural conditions was not found successful, it was thought that satisfactory results might be obtained if water is pumped from the Nullah during flow tide so as to draw more quantity into the spill area for spill operation. As such water was pumped at Garia into the spill area of 180 acres during each flow tide at the rate of 35 million gallons per tide and released from the spill area during the succeeding ebb tide. This artificial operation of the spill area of 180 acres above Garia was not found effective in raising the ebb velocity above 3 ft/ sec. even with the proposed resection of the whole reach of the Nullah (8)

4. After careful examination of the whole reach of the Nullah from Kidderpore to Garia, as exhibited by 1945 survey, a scheme of systematic enlargement of the section of the Tolly's Nullah from Kidderpore to Garia by deepening as well as widening was worked out . This scheme was examined in the model. After a series of model experiments with and without spill areas (9) a scheme with suitable sections of the Nullah with proper alignments were obtained. It was found that with this scheme of resectioning the entire reach of the Nullah, (Fig.4) the ebb velocity in the upper reach would improve satisfactorily and when a spill area of 180 acres is opened near Garia for free spill operation, the Tolly's Nullah would be maintained in good condition.

PART II. TIDAL COMPUTATIONS

Experiments on tidal models are required to be carried out under specific limitations whose effects on the results of such experiments are not clearly known. For this reason it is quite often desirable to apply mathematical methods to the treatment of tidal propagation. The differential equations of tidal motion can be obtained easily but since the mathematics of tidal motion is extremely complicated their solutions are not possible directly. Attention has therefore been devoted to try for approximate solutions by indirect methods with the help of approximated simplification in the sectional contour of the channels.

Such attempts have been made in the United States of America, France, Belgium, Germany and Holland,—specially in the last named country where sea and tidal action have a place in the life history of the nation. The development of mathematical methods of tidal computation has taken place in that country during the last half century and successful application of these methods has been made for different projects. These mathods are described here in brief.

Simplified Approximation of the Channel Section and Adjoining area

In general, there are diverse irregularities in the shape of the channel, both in sectional contour as well as in the longitudinal direction. With these irregularities the channel section is not amenable to mathematical treatment. In order to make such treatment possible the channel section is approximated to a simplified form which ignores the minor local irregularities but retains the overall long range characteristics.

In the first place the channel bed is envisaged as composed of two portions, viz., the central channel proper, which stores water as well as transports or carries water mass in the longitudinal direction, and some other portions like shoals or lateral basins, which do not have a significant carrying function but, nevertheless, take part in the storing function. In tidal rivers this storage becomes important since it changes significantly during the tidal cycle with the rise and fall of water level.

A second simplification is obtained by dividing the entire length of the channel into sufficiently small segments where the transverse sectional profile may be considered to be uniform, i. e. the channel is considered a uniform prismatic channel. When there is a significant change in the sectional contour at some point, this point may be taken as a dividing point.

With these two assumptions the equations of motion are sought to be solved mathematically to give the flow conditions. The success of the computations ofcourse depends upon the validity of these assumptions.

Differential Equations of Motion.

The following notations and symbols are used hereafter to denote the different factors involved in the equations:

h = height of waterlevel above datum ;
v = velocity of flow in the length direction x ;
B = width of storage i. e. water surface width ;
b = width of channel proper (approximated) ;
d = depth of water in approximated channel ;
A = sectional area in channel proper = bd ;
Q = rate of discharge = Av ;
C = Chezy's constant.

The water in motion is assumed to be incompressible.

The external forces acting on the elementary water mass in motion are (*i*) the frictional resistance due to shear action of the moving water on the channel bed and (*ii*) the wind pressure due to shear action of the air on the water surface. Let i_r and i_w denote the slopes sufficient to compensate for the stresses due to resistance and wind pressure. In shallow waters the frictional resistance becomes quite significant. The wind pressure is appreciable for computing storm tides, but may be neglected in ordinary cases.

The tidal motion in a channel is governed by two equations, viz. the equation of continuity expressing the balance of the accumulation in storage volume with the difference between the incoming and outgoing water, and the dynamical equation following Newton's second law of motion expressing the balance of the forces and the inertia. These two equations are easily derived as

$$\frac{\delta Q}{\delta x}+B\frac{\delta h}{\delta t}=0\ , \qquad (1)$$

and

$$\frac{\delta v}{\delta t}+v\frac{\delta v}{\delta x}+g\frac{\delta h}{\delta x}+g(i_r+i_w)=0. \qquad (2)$$

If there is also a lateral discharge q_e per unit length, then there is a third term q_e in equation (*i*). In ordinary cases we take $q_e=0$ also $i_w = 0$. The value of i_r is given by Chezy's formula viz.

$$i_r = \frac{v|v|}{c^2d}$$

The dynamical equation then assumes the from

$$\frac{\delta h}{\delta z}+\frac{v}{g}\frac{\delta v}{\delta z}+\frac{1}{g}\frac{\delta v}{\delta t}+\frac{v|v|}{C^2d}=0, \quad \ldots.(3)$$

Or,

$$\frac{\delta H}{\delta z}+\frac{i}{g}\frac{\delta v}{\delta t}+\frac{v|v|}{C^2d}=0 \ldots\ldots\ldots\ldots(4)$$

Equations (1) and (3) express Q, v and h in differential forms with respect to x and t. Since Q and v are related, the soultion of these equations would give Q and h, or v and h, in terms of x and t.

Solution of the Equations

Different methods have bee ntried to obtain, by indirect means, approximate solutions of the above equations which would give the flow conditions at any point subject to known boundary conditions. These can be broadly grouped under two categories, viz., harmonic methods and methods of numerical integration. Of these methods, the itoration method developed by Dronkers (²) of Holland is one of the most refined and has been widely used in recent times for computations for different rivers.

The solution by the iteration method in the final form is given below for reference :

$$Q'=Q+\dot{B}hx+\frac{B/\dot{Q}/Qx^2}{C^2b^2d^3}+\frac{B\dot{Q}x^2}{2gbd}-\frac{3BQ/Q/\dot{h}x^2}{2C^2b^2d^4}, \quad (5)$$

and

$$h'=h+\frac{Q/Q/x}{C^2b^2d}+\frac{\dot{Q}x}{gbd}+\frac{B/Q/\dot{h}x^2}{C^2b^2d^3}+\frac{B\ddot{h}x^2}{2gbd}$$

$$-\frac{(B+b)Q\dot{h}x^2}{gb^2d^2}+\frac{B^2\dot{h}^2x^3}{3C^2b^2d^3}, \ldots\ldots(6)$$

where

$$\dot{Q}\equiv\frac{\delta Q}{\delta t},\ \ddot{Q}\equiv\frac{\delta^2 Q}{\delta t^2}, \text{ etc.,}$$

x is the length of the segment, Q′ and h′ are the values of Q and h at the upstream end and all the parameters on the right hand side denote values at the downstream end of the segment. Slight variations of these forms have been used at different times. These equations help to compute onwards (i. e. in upstream direction) from the downstream end, segment by segment.

Practical Application of the Solutions

The first step in the practical computations is the schematic division into segments, referred to earlier and also determination of the simplified average section for each segment. This is to be done from the contour survey data of the entire area, and calls for discretion of the part of the computer.

For starting the computations the tidal gauge and discharge curves at the extreme downstream point are required. The representative tidal gauge curve is obtained from observations, while the discharge curve is initially estimated roughly from the rate of change of storage volume for the entire length. The tidal gauge curve at the downstream extremity and the upland discharge at the other extremity, (nil discharge for a closed basin) serve as the boundary conditions. Any other observed gauge data at intermediate points serve as check on the computations. Starting from the downstream end, repeated use for formulae (5) and (6) for successive segments gives the flow conditions at different points. At the upstream end, the known upland discharge is to be satisfied. This agreement is to be obtained by tiral and error, which often involves considerable error. When this has been attained, the schematic simplified model of the river may be said to have been proved, like proving a hydraulic scale model.

For studying the effect of any proposed change in the river in the shape of structures as remedial measures, this alteration is introduced in the boundary conditions and the computations done over again. The flow conditions throughout the river are thus computed under the altered conditions. The difference noticed from the originally computed flow conditions are then studied to give the effect of the alterations. This technique is also similar to that applied in experiments with scale models.

Some actual Computations—The Tolly's Nullah

Some of the useful contributions of tidal computions in the practical field may be stated here. Thus in the course of the investigations under the great physicist Lorentz (¹) for the enclosure of the Zuider

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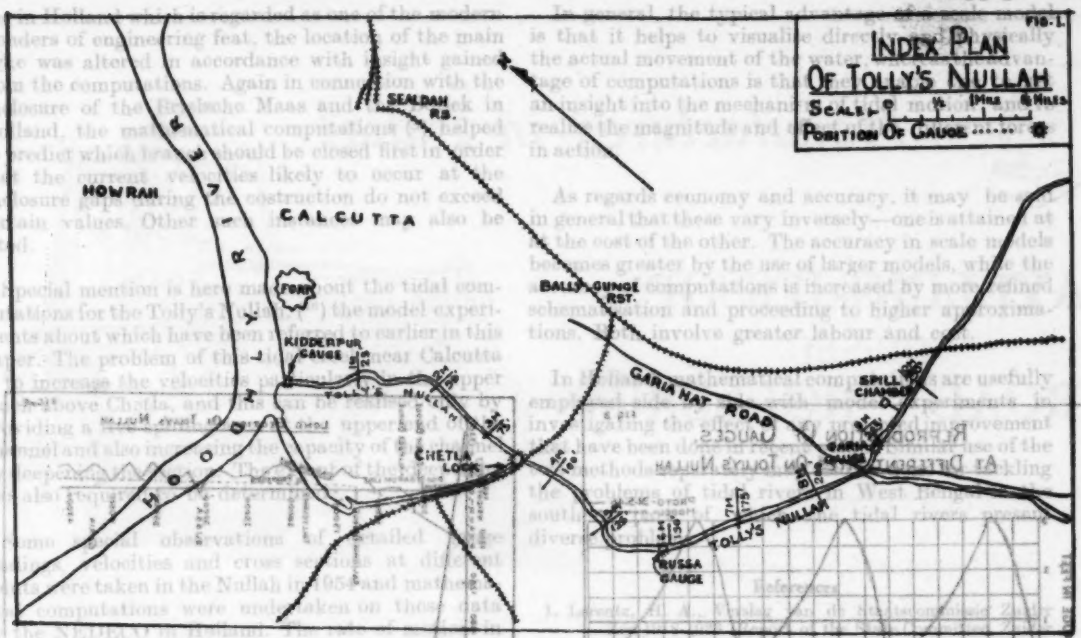

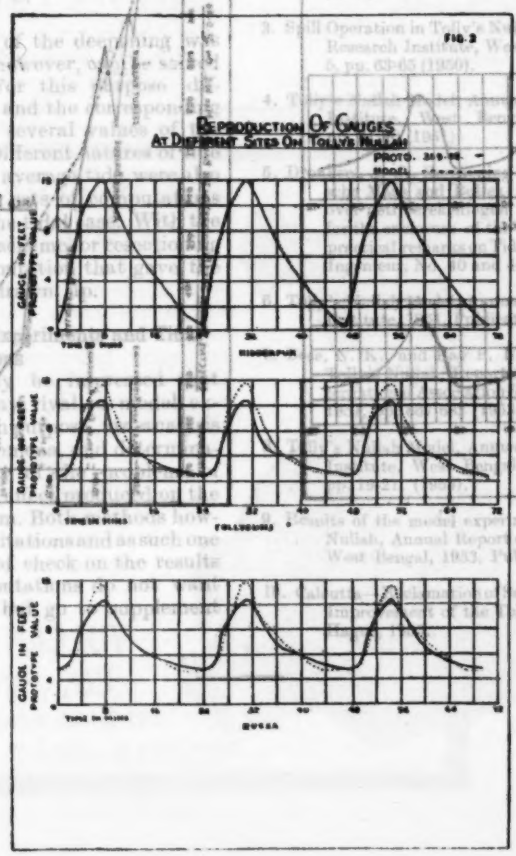

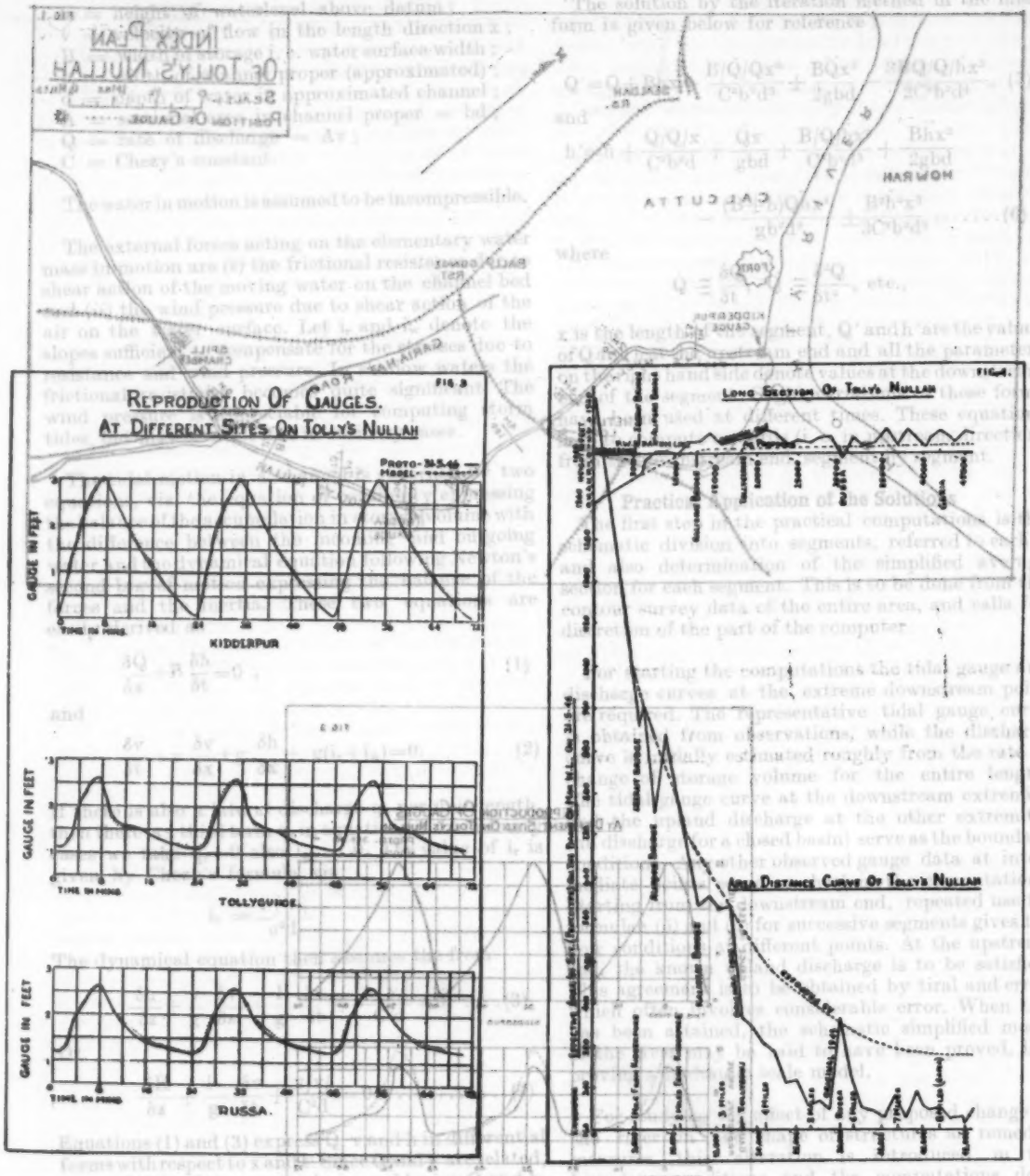
INDEX PLAN
OF TOLLY'S NULLAH
CALCUTTA
HOWRAH
FORT
REPRODUCTION OF GAUGES.
AT DIFFERENT SITES ON TOLLY'S NULLAH
FIG. 3
PROTO-
MODEL-
GAUGE IN FEET
TIME IN MINS.
KIDDERPUR
TOLLYGUNGE.
RUSSA.
LONG SECTION OF TOLLY'S NULLAH
FIG. 4.
AREA DISTANCE CURVE OF TOLLY'S NULLAH

Zee in Holland which is regarded as one of the modern wonders of engineering feat, the location of the main dyke was altered in accordance with insight gained from the computations. Again in connection with the enclosure of the Brielsche Maas and the Botlek in Holland, the mathematical computations (5) helped to predict which branch should be closed first in order that the current velocities likely to occur at the enclosure gaps during the costruction do not exceed certain values. Other such instances may also be cited.

Special mention is here made about the tidal computations for the Tolly's Nullah, (10) the model experiments about which have been referred to earlier in this paper. The problem of this tidal creek near Calcutta is to increase the velocities particularly in the upper reach above Chetla, and this can be realised only by providing a free spilling area at the upper end of the channel and also increasing the capacity of the channel by deepening the section. The extent of the deepening was also required to be determined.

Some special observations of detailed gauge readings, velocities and cross sections at different points were taken in the Nullah in 1954 and mathematical computations were undertaken on these data by the NEDECO in Holland. The rate of motion in the Nullah in the existing state was initially computed and compared with actual observations at different points. This gave valuable informations about the nature of tidal motion and the value of the resistance and, in particular, of Chezy's C.

The question of the extent of the deepening was studied next. Such a problem, however, can be solved only by trial and eerror. For this purpose different values of the deepening and the corresponding enlargements were tried with several values of the area of the free spilling area. Different natures of tide like spring tide, neap tide and average tide were also considered. In all twelve such sets of computations were performed, working out the tidal case. With the help of theresults of all these, a scheme for resectioning of the river following the computation that gave the most favourable results was drawn up.

Comparison between Model Experiments and Tidal Computations

At the very outset it may be impressed that tidal computations are, in no way, rival to model experiments. Both have a common purpose, viz. analysis and reproduction of tidal phenomena, and determination of the solution or remedy of the problems of tidal rivers by considering the effect produced on the tidal motion of the entire system. Both methods howeverhave got their inherent limitations and as such one method may be used as a sort of check on the results of the other. Thus tidal computations do not want to replace model experiments but go to supplement the findings therefrom.

In general, the typical advantage of a scale model is that it helps to visualise directly and physically the actual movement of the water, whereas the advantage of computations is that they enable one to get an insight into the mechanism of tidal motion and to realise the magnitude and effect of the different forces in action.

As regards economy and accuracy, it may be said in general that these vary inversely—one is attained at at the cost of the other. The accuracy in scale models becomes greater by the use of larger models, while the accuracy of computations is increased by more refined schematisation and proceeding to higher approximations. Both involve greater labour and cost.

In Holland, mathematical computations are usefully employed side by side with model experiments in investigating the effect of any projected improvement that have been done in recent years. Similar use of the two methods separately may also be done for tackling the problems of tidal rivers in West Bengal in the southern part of which the tidal rivers present diverse problems.

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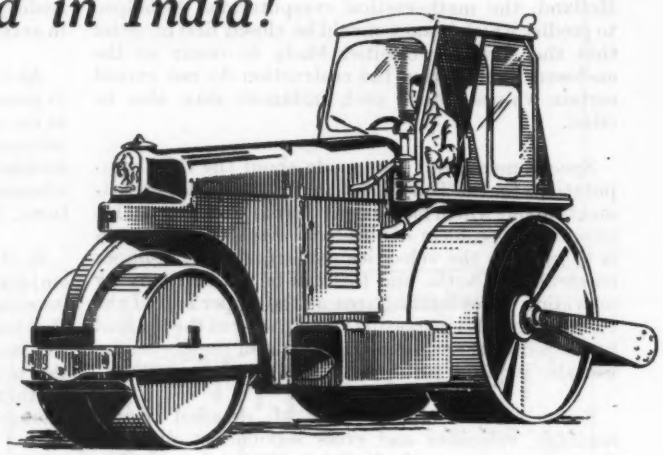

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Economic Aspects of Drainage in the Lower Reach of Damodar

By SATYAKAM SEN

FLOWING water possesses extreme economic potentialities combined with the gravest danger. On the one hand, it sustains life and also provides the means for advancement of civilisation; on the other, it not only destroys life directly, but also does soindirectly by interfering ruinously with the procurement of the basic needs of human existence, particularly food, and shelter. This double-edged activity of river with with the resulting economic repercussion on society as a whole, makes consideration of the economic aspects of drainage of great importance in any comprehensive hydrological study. This portion of the text is therefore devoted to providing the indication particularly of how the human settlements and agricultural practices as the basic economic aspects have come to be distributed in the lower reach of Damodar.

Floods and Damage

Floods occur in the lower reach of Damodar during monsoons (i. e. June to Mid-Oct). Peak flow with a discharge of round about 600,000 cfs was recorded for the years, 1823, 1840, 1913, 1935 and 1941 respectively Peak discharge of about 650,000 cfs. was recorded twice in recent times, namely in August 1913 and August 1935. The corresponding flood volumeswere 3.7 million acre ft. and 1.47 million ac. ft respectively. From the available records of historical nature, it is found that the flood of late July 1840 was also similar in size to that of 1913, the flood of August, 1823 however was considerably larger. Floods are reported to have occurred also in 1882, 1890, 1898, 1901, 1902 1903 1905, 1907 and 1909.

The maximum flood discharge in the Damodar River during the period 1857 to 1917 (61 years) as observed at Raniganj is available (see table 39) from E. L. Glass's report which was submitted to the then Bengal Govt. in 1918. Corresponding data for the period 1935 to 1954 (20 years), as observed at Rhondia, are given in Table 40.

TABLE No. 39

During 61 *Years* (1857-1917)

No. of extremely abnormal floods	(above 450,000 cusecs)	.. ..	.. = 1
No. of abnormal ,,	(,, 300,000 ,,	.. ..	.. = 12=20%
No. of normal ,,	(bet. 200 to 300,000 ,,)	.. ..	.. = 33=55%
No. of subnormal ,,	(below 200,000 cusecs)	.. ..	.. = 15=25%

TABLE No. 40

During 20 *years* (1935 *to* 1954)

No. of extremely abnormal floods	(above 450,000 cusecs)	.. .. ..	.. = 2
No. ,, ,, ,, ,,	(,, 300,000 ,,)	.. .. ..	.. = 6
No. ,, ,, normal ,,	(200,000 to 300,000 ,,)	.. .. ..	.. = 9
No. ,, ,, Subnormal ,,	(below 200,000 ,,)	.. .. ..	.. = 3

The data from Glass's report show that discharge in the case of about 55% of floods ranged between 200 to 300,000 cusecs, and only in 20% cases the discharge was above 300,000 cusecs. On the other hand extremely abnormal floods with discharge values of 450,000 cusecs and above were rare phenomenon.

The size of the river Damodar is small but it ranks high amongst the Indian rivers so far as its destructive capacity is concerned. The left Damodar embankment has been breached frequently by floods. The flood damage which has often been caused in that way by the river has always been heavy. The resulting floods, due to the breaches, have interrupted the road and rail communications, and also affected the fertility of the innundated agricultural lands of the lower reach.

Much damage to life and property occured as a result of the August 1935 flood on right bank of the Damodar river, particularly in the vicinity of both Khandaghosh and Raina. The moderate flood of 1943,due to a breach of the left embankment, innundated vast areas lying to the west of Calcutta.

For want of adequate statistics, it is very difficult to evaluate the exact extent of damage due to flood during the years under consideration. However, "damage by minor floods to the paddy crop can, on an average, be estimated at Rs. 2,550,000 annually. If another Rs. 500,000 is added to cover damage to communications, buildings, etc. the average annual flood damage may be assessed at approximately Rs. 3,050,000 ([5o]). Thus the floods in Damodar have often times led to considerable disturbing effect on the economy of the region.

Drainage and Agriculture

Agricultural practices have prevailed for the last several centuries in the lower reach of Damodar. Centuries back quite free drainage conditions existed in the region. The river was less disturbed by man ; topdressing of siltwas doneby flood flushes, population pressure on soil was less, and the irrigation practices were not very prominent. As the drainage courses of the Damodar shifted, the decaying drainage lines were renovated by constructing irrigation canals. On the left bank of Damodar, the irrigation area has been increased tremendously within the last 75 years. In 1881 the Eden canal was constructed. In 1890 the crop figure in the irrigated area was 9693 acres. Later on in 1932 Damodar canal was constructed. Now *D.V.C.* canals are going to irrigate many acres of land. The area that can be irrigated from the Durgapur Barrage has been estimated at 1,044,000 acres, inclusive of the 185,000 acres already under irrigation. About 300,000 acres will be provided for Rabi irrigation. But all these areas are the moribund, decaying or decayed drainage lines of Damodar.

The main kharif crop of Damodar-Hooghly riverine plain is Aman paddy. The crop distribution of 1943 shows that this area is occupied by medium Aman. Fine Aman is grown in Shyampur where the Damodar reach is completely tidal. Coarse Aman is grown in the lowlying plains of Kedarmath and the northern tract of what was known formerly as the B. N. Rly. line. The flood plains between Madaria khal and Damodar river are where market gardening crops and grams are cultivated.

Field survey shows that the Aman is confined to the southern side, particularly below Amta. Regarding the crop, no significant distributional change has been noticeable since 1943. In the current year of 1956, the Aus paddy is found to spread over the area ; but there is no intensive zone or localised area where this variety of paddy is cultivated. At present the area under Aus is gradually diminishing as the cultivators are now more inclined to grow jute for its better marketing value. As for the distribution of jute and potato it is observed that Serampore subdivision is the zone where jute, with potato following it, is grown intensively. The area under Boro paddy is very limited and its cultivation is practised on a small scale in the P.S. Jangipara and Amta. In course of of his field work, the writer noticed that below Jamalpur bifurcation , where the river discharge decreases considerably, rabi crop is intensively cultivated along the banks or in the river bed by means of the Donga technique (photo 16 & 17). The cultivation

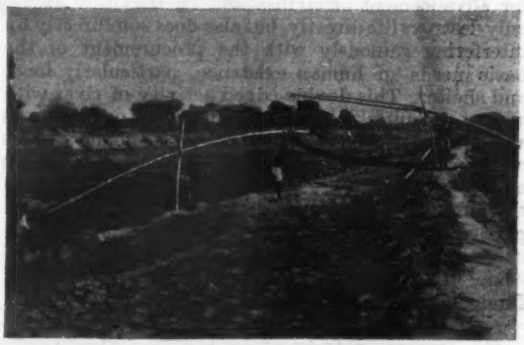


Photo No. 16—Field irrigation by Donga technique.

Photo No. 17—River fringe cultivation of Rabi corp near Amta.

of cash crops like jute, and also of market gardening crops, is making its appearance in the agricultural scenery of the area. When the D.V.C. canals and the resuscitation of the old drainage channels will be completed, the acreage of agricultural crops is most likely to be devoted in a large proportion to particularly the rabi crop cultivation. The Lower Damodar Valley having a thick, fertile topsoil and also being in proximity to urban markets is very suitable for Rabi cultivation. For Rabi crop cultivation, as a second

crop, there is need for an external supply of 9 to 12 inches of water even during the dry weather. The regulated release from Tilaiya, Konar, Maithon and Panchet will give a continuous flow of 3000 cusecs for the dry season (November to May).

Agriculture in the Trans Damodar area

In Beadle's time (1856) the trans-Damodar area was practically a vast sheet of land (innundated and more or less impossable) which represented a definite tract where cultivation was not practised. But in lands at higher levels, rice and sugarcane were the principal crops. Mulberry was cultivated near the drainage channel, i.e., near Jamalpur, Modeepur (present Mohiddipur) and Puspoor. Hemp was cultivated near Moja Damodar.

With the removal of the right embankment agriculture has flourished over the entire area from the availability of spill water of Damodar floods (see fig. 60). Map also shows that the rise of water in the agricultural field is the highest between Harinakhal and Damodar (particularly along the left bank of Damodar); and naturally the percentage of crops destroyed is also high here. The effect is moderate between Harinakhal and Mundeswari. Between Mundeswari and Dwarakeswar the effect is rather small, as one finds on approach towards the west and the south. The flood water is necessary to flush the trans-Damodar area every year from a sanitary point of view as well as from that of fertilisation of the land by the spill. Indeed, if 1.6 depth of the flood water passes over the bank and spills over the area, the purpose may be served. Dr. S. C. Bose's survey in 1943 shows that in this area where Aman is predominant (though one Boro island is also noticeable) pulses and market gardening crops are cultivated intensively. Tobacco, Hogla, and Madurkatis are available between the flood plains of Moja Damodar and Damodar.

Field survey conducted during 1956, denotes (see fig. 71) that the large tract below Pursura-Harinkhola line have become a dry zone. No flood or spill water over-runs the area, and crops do not thrive well. Above Pursura—Harinakhola line, the area is also inclined to be a dry one. A certain amount of cultivation, particularly rice, prevails in the low-lying pockets or depressions.

The low-lying areas of trans-Damodar tract, which were previously subject to innundation, are today under Rabi crops, like potato for example. But Rabi cultivation is limited, and so also is that of jute, the area under these kinds of crop being quite small in relation to the total area cultivated. The largest Boro tract, next to Amta is Khanakui. As one proceeds alone on a downward journey in the lower reach of Damodar (P.S. of Bangan, Uluberia and Shyampur), one will pass by the agricultural fields which come under jute, Aus, and Boro among the Khariff crops, and under potato, mustard and onion, among the Rabi crops, although the areas under these latter are negligible. On the other hand Aman paddy is so pre-dominant that the whole area may be said to be under Aman paddy. That is, Aman paddy is the most dominant crop. Trans-Damodar area of course lies outside the D.V.C. commanded zone. Low lying nature being the feature of topography, the question of drainage here becomes more prominent than the problem of irrigation.

Drainage and Industries

Drainage does not play an exclusive role in the location of industries in the lower reach of Damodar. The concentration of heavy industries is greater in the Raniganj-Asansol region; and this is probably due to occurrence of coal about that area. However, besides power such as coal provides, the heavy industries also consume water to a very great extent. So we observe incidence of various kinds of industries, like paper mills Aluminium, Ceramic and Transport-equipment factories, etc. by the river and the coal basin. Most of the industries of the lower Damodar Valley, are located within 4 miles from the river bank (see Fig. 61). Hence the part played by the river in the location of industries, though relatively small is still an important one. For this reason, with the completion of the Durgapur barrage, several industrial concerns have already been trying to set up some large industrial establishments in that region. Durgapur will also have her steel plant soon. Driver ([51]) holds the views that foundries and metallurgical industries, wood products industry, stone quarrying, chemical industries, silica brick factory plant, sugar mills, and cotton spinning mills would be suitably locate at Durgapur and its neighbourhood and along the canal side. It is to be noted in this connection that industries established in the Damodar catchment above Durgapur will be likelyto discharge effluent, containing salts and chemicals, into the river. Such an event will bring about deterioration of cultivated lands. Besides, the industrial pollution of water will result in incidence of water-borne diseases in the area. Deterioration of the general health of the people and the cattle of the area is thus a high probability.

The relationship between drainage and industries in the lower reach of Damodar is therefore especially complex, the good and the evil being mutually involved.

Drainage and Communication

Damodar river was, once upon a time, a navigable water-way upto Asansol; at that time Raniganj coal used to be carried to the industrial areas of Calcutta including the neighbourhood, by riverine traffic. Damodar river traffic, even 200 years ago, used to be busy about conveying coal, paddy and other agricultural products. Several prosperous villages indeed came to exist on the map wherever the river bed happened to be of sufficient depth to allow loaded boats to ply.

Previously Kana Damodar as well as Kana and Kunti Nadi used to carry a good quantity of river-borne trade. Due to the rapid deterioration of the river channel of the Damodar through siltation, particularly below Selimabad and Jamalpur, low upland water discharge, infrequent influx of tidal water on the tidal reach, and also the shifting of the river bed, navigation was great y hampered. Below Jamalpur, the Damodar river and its distribut aries served the agricultural population to a great extent. Country boats used to handle all the agricultural traffic of the interior of the Hooghly and Howrah districts. Below Ahalya Bai Road (Arambagh-Champadanga line), the small river—channels formed important arteries maintaining intimate economic and

social links between one village and another. But today most of the drainage channels have been completely silted up, and no country boats can ply on them except during the extremely high floods in monsoons. Riverine traffic by country boats can therefore exist now a days only during a small fractional part of the year, instead of during the whole year as previously. The inland country areas, like Khanakul and other such places, were mutually linked in the earlier days by inland waterways. But now many of those channels have come silted up. The rural economic contacts are at present suffering as the result of inadequate and difficult means of communication. Even the limit of the tidal flush which alone now allows persistence of water traffic during the dry season, reaches only upto Amta. Fig. No. 62. depicts the approach of country boats through the drainage channels during the rainy season as well as the dry season. During the dry season the boats ply only with the tides (caused by the full and the new moon). Considerable amount of commodities are of course handled at such times. If the river is in spate, the boat can even proceed quite a long way inland. Table No. 41. shows moderate type of vessels plying along

Photo No. 19—Boats left high and dry by receding tide.

The main purpose of this canal is to serve the irrigation needs, but as stated above, it is intended to be utilised for navigation also, and thus secure a convenient means of communication without incurring too much capital outlay. The bed width of the canal varies from 172′ at the head, to 60′ at the tail end.

TABLE No. 41

Name of the rivers	*Navigable length upto*	*Max. draft for high water*	*Max. draft for low water*	*Max. length & length of vessels plying*
Rupnarayan	Bandar	4′0″ to 5′0″	3′0″ to 4′0″	130′0″×19′0″
Dwarakeswar	Kongra	2′6″ to 3′0″	2′0″ to 2′6″	50′0″×18′0″
Damodar	Amta	4′0″ to 3′0″	3′0″ to 4′0″	75′0″×10′0″
Hooghly	Uluberia	sea going vessels of all size and draft		

the Damodar (cf. Rupnarayan and Dwarakeswar). About 3′-0″ to 5′-0″ of water becomes necessary for navigation by country boats.

D.V.C. Navigation canal

This, situated on the left bank of Damodar river, is an irrigation cum navigation canal. It takes its water off from the Durgapur Headworks.

Photo No. 18—Main Damodar canal near Durgapur Barrage.

It is proposed to maintain a clear depth of water of upto 12′ during the rainy season. But during winter and summer, when requirement of irrigation willbe very much reduced and the discharge through the canal accordingly restricted the minimum depth of water of upto 8′ will be maintained. "In fact in our design we are providing for a minimum 9′ depth of water with an allowance of 1 foot for siltation. This will enable crafts and barges of upto 6′ draft to ply in the canal throughout the year. As the supply in the canal during winter and summer will be considered reduced, it is absolutely essential to locate cross regulator (and consequently locks) at closer intervals to maintain a minimum draft of 8 in the canal. The location of the locks will naturally interfere with the speedy movement of crafts and barges. As they cannot be avoided in the interest of the required draft, our navigation should be so adjusted as to fit in with the above arrangement. The design of the locks has been made so as to serve the requirements of two 200-ton capacity barges, so that in one operation, two barges can be taken from upstream to downstream and similar two from downstream to upstream. This arrangement will somewhat help in speeding up the journey inside the canal, which is expected to be 4/5 days for the entire canal. The maximum velocity in the canal, when the canal will run the full discharge, will be of the order of 4 per

sec. But such condition will not prevail for a period of more than 20 to 25 days in a year. During most of the period, it will be varying from 2 to 3 sec. It may also be pointed out that fast moving vessels may not be allowed inside the canal so that the canal banks may not be endangered by wave action and shore wash. Incidentally this canal is not lined anywhere and will be a purely earthen channel, with the side slope varying, from 2 horizontal to one vertical (5²). Thus the construction of the navigable canal which passes through the rich economic hinterland, will relieve the transport problem, and thereby also the traffic congestion which now hinders and hampers the in-and-out flow of raw materials and products of the great Calcutta industries. This canal will also link up two important river basins, viz., those of Damodar and Bhagirathi. The canal traffic will handle bulky materials, such as coal, finished industrial products of the two industrial zones and some agricultural commodities for transport to their respective destinations. This constructed waterway is running almost parallel to the Grand Trunk Road, and the main line of the Eastern Rly. But as indicated by Mukherjee (ibid) so many lockgates will probably be somewhat of a handicap to speedy transport. For this one reason it is justifiable to think that the canal will offer no solution for the supply of perishable commodities.

The probable important transport commodities to be handled by the Damodar canal are coal, bunker coal, and pig iron, these being sent on to Calcutta from the Asansol Raniganj industrial region. The return cargoes from Calcutta to Durgapur will mainly consist of jute bags for the canal side mills and factories and the rice mills of the Asansol area. It will also be helpful in conveying salt, oil roducts, cement, heavy machinery etc., such as may be required for the Asansol-Raniganj area.

Previously the entire lower Damodar area was served by waterways and roadways railway traffic did not exist prior to the middle of the 19th century. The construction of Damodar left embankment was closely linked up with the development of roadways and traffic routes in the Damodar Hooghly inter riverine plain because it reduced the flood intensity, and thereby ensured security of the roads and safety of travel. On the other hand the removal of the right embankment of Damodar happened to be the reason for spill in the Trans-Damodar areas. The entire area would be innundated during floods. No permanent roadstructures could therefore be made. The boats provided the chief mode of transport. Today, the flood intensity has become reduced in the spill area (the trans-Damodar area) with the construction carried out under the D.V.C. Project. Now the previously innundated Trans-Damodar tract and many other areas have become sufficiently dry so as to allow construction of road-structures, which is to be done.

In the Damodar basin, exploitation of natural and industrial resources was aided by water transport. Later on, this mode of transport was replaced by railways and motor vehicle traffic. Now again the D.V.C navigation canal will be able to regenerate the water-borne traffic, thus supplementing the transport carried on by roads and railways. With these three heads of traffic lines operating, the prevailing congestion in the matter of inland transportation of goods will be greatly relieved.

Drainage and Settlement

The settlement pattern in the lower reach of Damodar is closely linked with its drainage conditions. Densely populated villages are situated along the river, especially where a steady supply of water is ensured. Moreover, the area of the lower Damodar Valley being an agricultural one, occurrence of excess or deficiency of flood water naturally plays a significant part in determining the size and shape of the settlement pattern.

There are three distinct types of settlement which are found in the area under investigation (see fig. No. 63). These are specified below :—

1. *Bee-hive Settlement*

It is found mainly in the Mohonpur village e.g. areas where drainage lines are either absent or not very prominent e.g. Rayna thana. Particularly this type of settlement is noticeable far off from the river. Tanks predominate as source of water in such settlements, and habitations happen to cluster around them.

2. *Irregular Aggbomeration with Dense Scattered Matrix*

This pattern occurs particularly below gaighata Bakshi khal. Bagnan is the focal point. Here drainage does not play a prominent part, there being other factor which are responsible for the growth of the settlement.

3. *Linear Type of Settlement*

It is found mainly along

(*i*) Kana Damodar
(*ii*) Damodar
(*iii*) Madaria Khal
(*iv*) Moja Damodar and
(*v*) Kana Dwarakeswar

Protruded patches of elongated shape of settlement are found between Kana Damodar and Damodar. Population concentration is high along the flood plains and along the embankments. Moja Damodar is a fine example of linear concentration of settlements along the flood plains. Settlement has developed in this way because Damodar discharge here has been insignificant. There is no chance of immersion taking place ; and also there is no question of any flooding or spilling disturbing the settlement.

Settlement Pattern between Damodar and Dwarakeswar

Even in recent years, a settlement would not develop along the Harinakhal and Mundeswari channel, probably because the discharge has grown high. Small elongated patches are, however, found above Arambagh-Champadanga road. Lower down, upto Gaighata Baxi-canal, embankments protect the flooding of the low lying areas. These low-lying areas are where rice is cultivated. Here land is being raised by constructing embankment, and small circular, irregular, elongated settlement patches are found along, or on the embankment side. The size and shape of the settlement pattern in this region is entirely dependent upon the topography and the embankment lines, and also on occurrence of small channels.

It was noticed by the writer in course of his field work that no permanent structures for dwelling houses are present in this area (Trans-Domodar spillarea). It is probably so because of preponderance of floodings.

Influence of drainage in effecting changes in the settlement patterns, such as have occurred from Rennel's time upto the time of the 1951 census, has also been noted. It is clear that prosperous villages and towns, in Rennell's time (1781), were confined to Kana Nadi and Damodar river (upto Amta). Most of such villages were located along Kana Nadi which during Rennell's time, was in moribund condition. Disastrous floods did not innundate the banks of the river over miles. Few spots of settlement developed on the old beds of Dalkishore and Behula river. These two rivers were not dangerous from the point of view of flood during Rennell's time.

On Beadle's map (1856) the most important towns and the notable and prosperous villages are situated the Lower Damodar. Very few prosperous villages are located far from the river. In 1856 most of the villages beside the Damodar river were located on the right bank instead of on the left (upto Champadanga).

About 1951, numeruos villages of population of 1000 or more have cropped up in a linear type, particularly along the old beds of Damodar. Today villages are more concentrated along the present Damodar river, Madariakhal, Kana Damodar and Kunti Nadi, Moja Damodar and Dwarakeswar. During Beadle's time (1856), few prosperous spots can be found to have occurred on Damodar khal (present Moja Damodar); rather the prosperous villages of that time apparently grew along Kana Dalkishone and Sankra Nadi. The linear type is disturbed below the Gaighata-Baxi khal. But on the channel (Mundeswari) where present discharge is high, villages with a population of 1,000 heads are few. From the study of the patterns as above, although the data are meagre, it is quite clear that any change in the character of settlements or the location of prosperous villages or even occurrence of villages with high population density is closely linked with the changes in the river courses and the prevailing drainage conditions (see chap. IV &V).

References

(50) Flood Damage and Flood Control Activities in Asia and the Far East (United Nations Pub.—Flood Control Series No. 1).

(51) Driver, D.C Industrial uses of the D.V.C.'s Durgapur Canal Industrial. India Vol. No. 6.

(52) A note on Navigation Canal—D. Mukherjee.

Note :—Table and Figure numbers are in continuation of the series of articles by the author in earlier issues of this journal. The concluding article will appear in the next issue.

Continued from page 123

An Integral View

much concerned at the very inadequate utilisation of irrigation facilities increasingly offered in these areas primarily due to the conservative agricultural practices that held good in the dry conditions but do not remain most efficient in the present context.

The problem of the Sunderbans area has been very interestingly presented by Mr. Gupta and Mr. Ray. It is unfortunate that opportunities were not available to the late Mr. Ray to experiment his ideas on a model or pilot scale in this area before his death. However, it may be worthwhile exploring its practical possibilities and its economics by others. The general trend of his argument on the whole seems sound and if experimental data justifies his approach, this State may open up a fresh area for settlement. But Mr. Gupta does not appear to accept Mr. Ray's approach. In any case there are no two opinions about the need to improve the headwaters; and here the Ganga Barrage Project is of immense importance in more respects than one We simply do not understand why there is so much hush hush about this project which is a matter of life and death for West Bengal.

Another outstanding pointer at the Symposium was the rich possibilities of development of a chain of chemical industries based on the Ranigunj coals. Let us hope with Dr. Lahiri that the prospects envisaged are based on proved data.

The need for more and more electrical power in West Bengal is undoubted. While hydroelectric possibilities of North Bengal are immense, our foresters are rightly alarmed at the prospects of increased timber industry and extension of tea plantations and the consequent deforestation of already thinned forests, thus threatening not only more floods but also rapid siltation of reservoirs, etc. Considered from this angle and from the point of view of the need to conserve metallurgical coal, the case for atomic power cannot be disregarded altogether. Economics of power per killowat is after all not everything, as has been rightly pointed out by Dr. Myrdal at the Sectional Meeting of the World Power Conference at Belgrade in June last.

The Symposium underlines one important conclusion—the need to have a broad perspective based on understanding and knowledge of our total environment. To the extent this will have been imbibed by the participants and by the readers of this Special, our purpose in organising it will be fulfilled. We shall be happy if we can carry forward this effort in other areas with the co-operation of all.

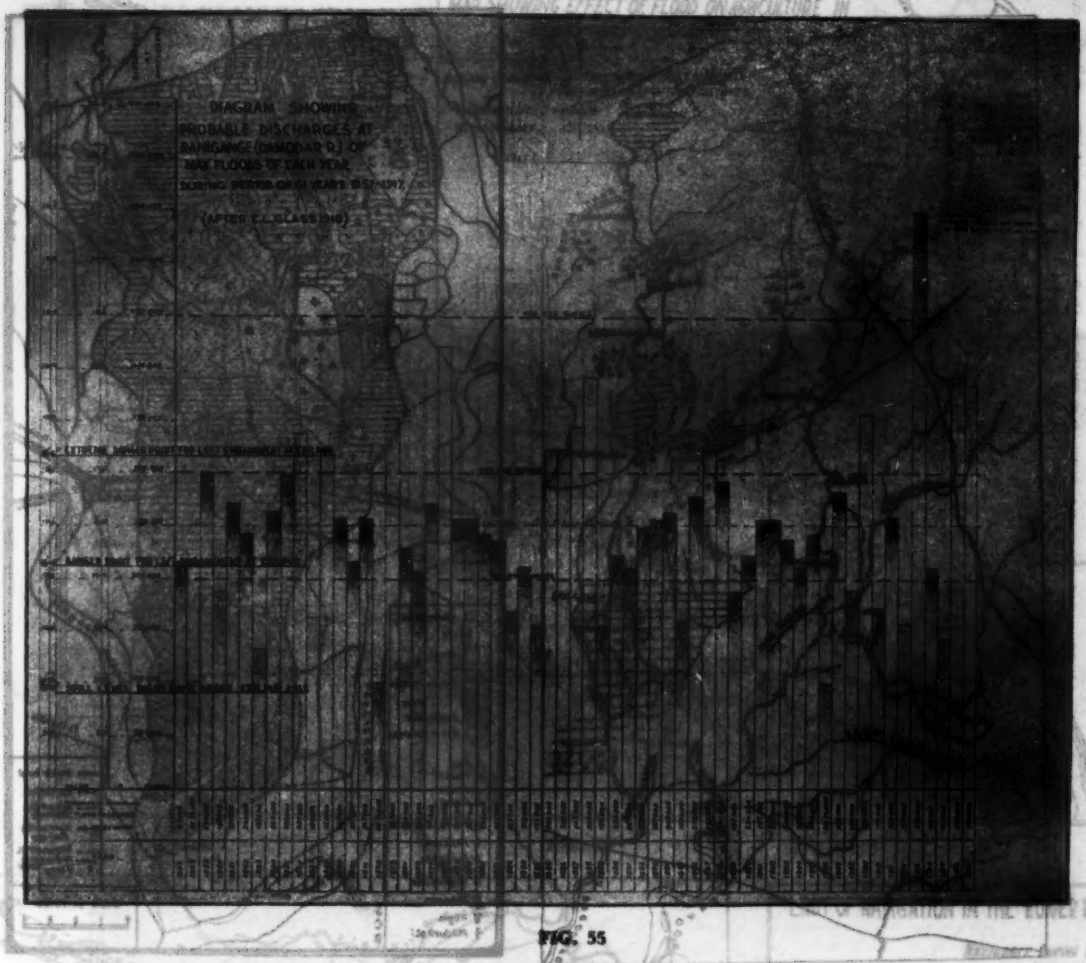


DIAGRAM SHOWING
PROBABLE DISCHARGES AT
RANIGANGE (DAMODAR R.) OF
MAX FLOODS OF EACH YEAR
DURING PERIOD OF 60 YEARS 1857-1917
(AFTER E.L. GLASS 1918)

FIG. 55

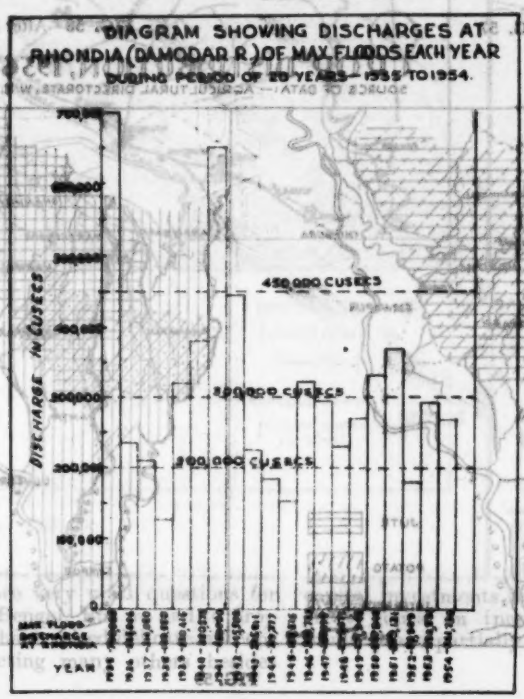


DIAGRAM SHOWING DISCHARGES AT
RHONDIA (DAMODAR R.) OF MAX. FLOODS EACH YEAR
DURING PERIOD OF 20 YEARS — 1935 TO 1954.
DISCHARGE IN CUSECS
450,000 CUSECS
300,000 CUSECS
200,000 CUSECS
0
MAX FLOOD DISCHARGE IN CUSECS
YEAR

FIG. 56

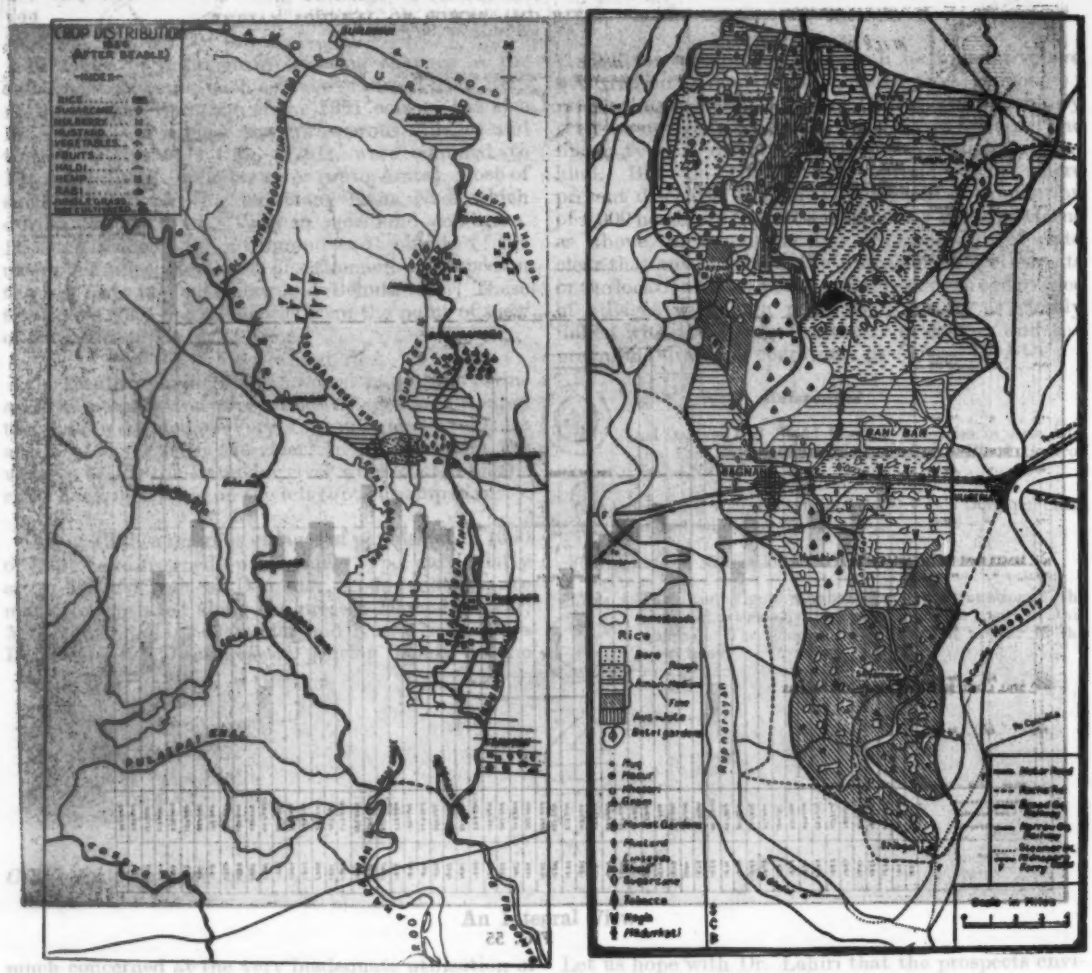


FIG. 57 FIG. 58—After Dr. S. C. Bose's Survey

CROP DISTRIBUTION, 1956.

SOURCE OF DATA:— AGRICULTURAL DIRECTORATE, W.B.

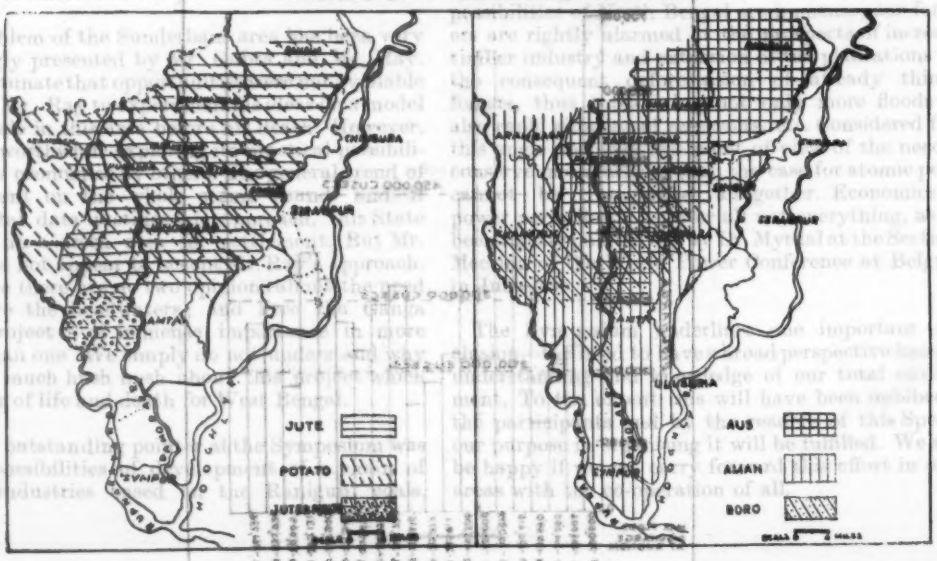


FIG. 59

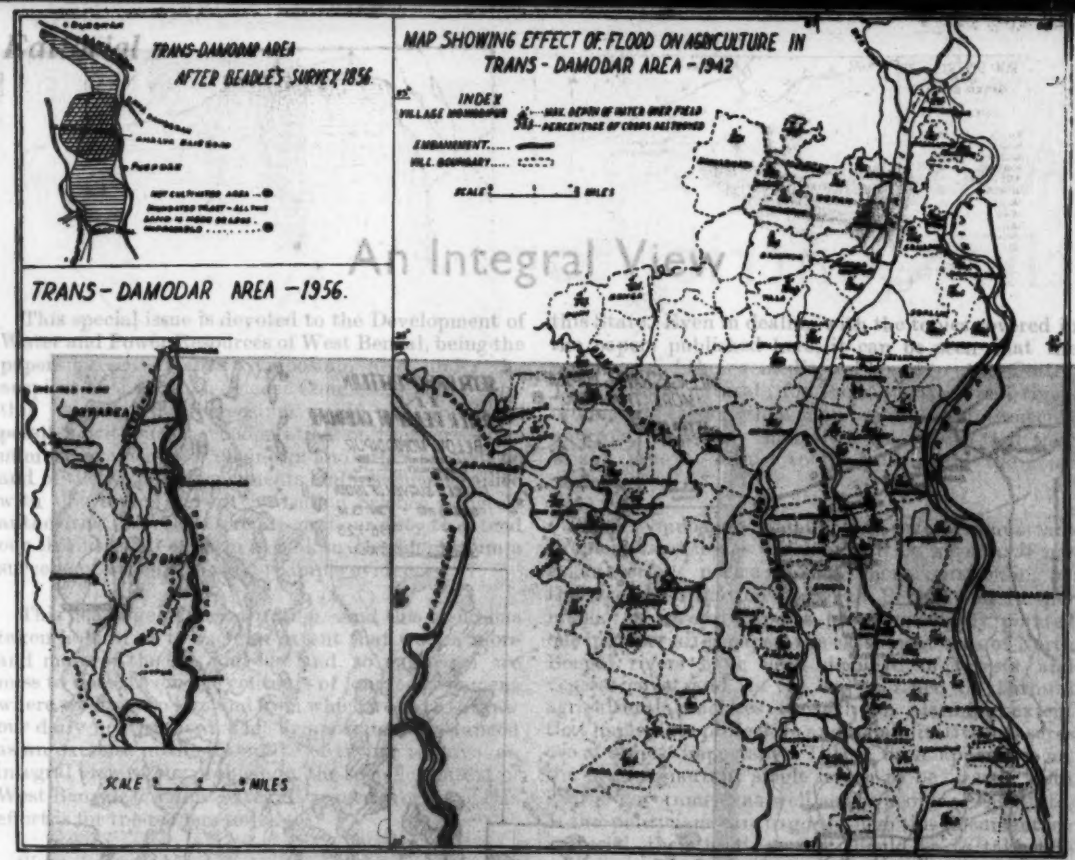

TRANS-DAMODAR AREA
AFTER BEADLE'S SURVEY, 1856
TRANS - DAMODAR AREA - 1956.
SCALE 0 1 2 3 MILES
MAP SHOWING EFFECT OF FLOOD ON AGRICULTURE IN
TRANS - DAMODAR AREA - 1942
INDEX
SCALE 0 1 2 3 MILES

FIG. 60

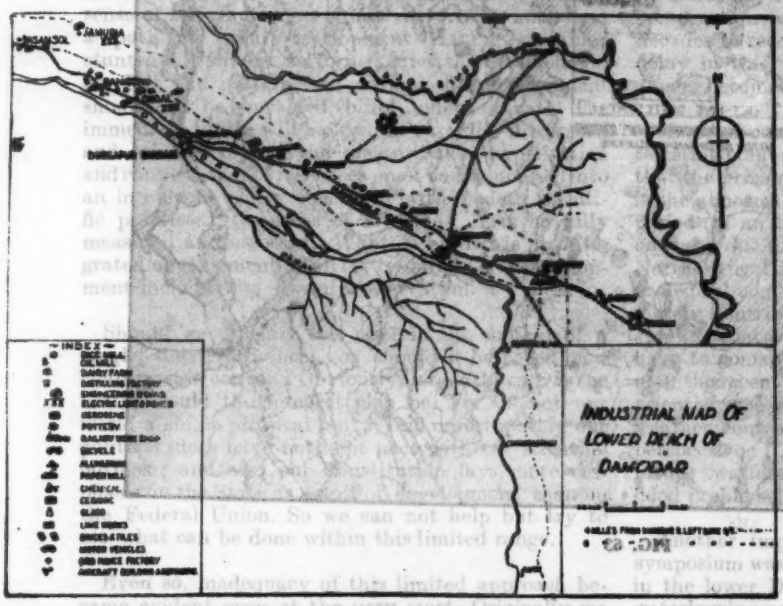


FIG. 61

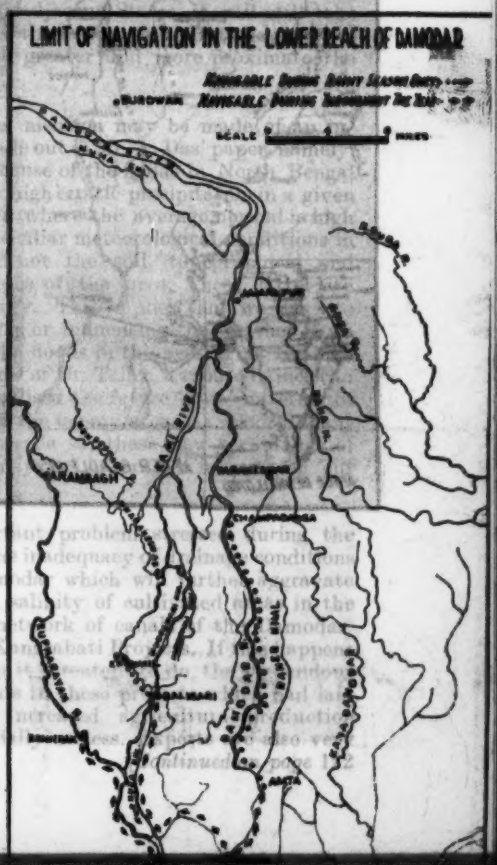


FIG. 62

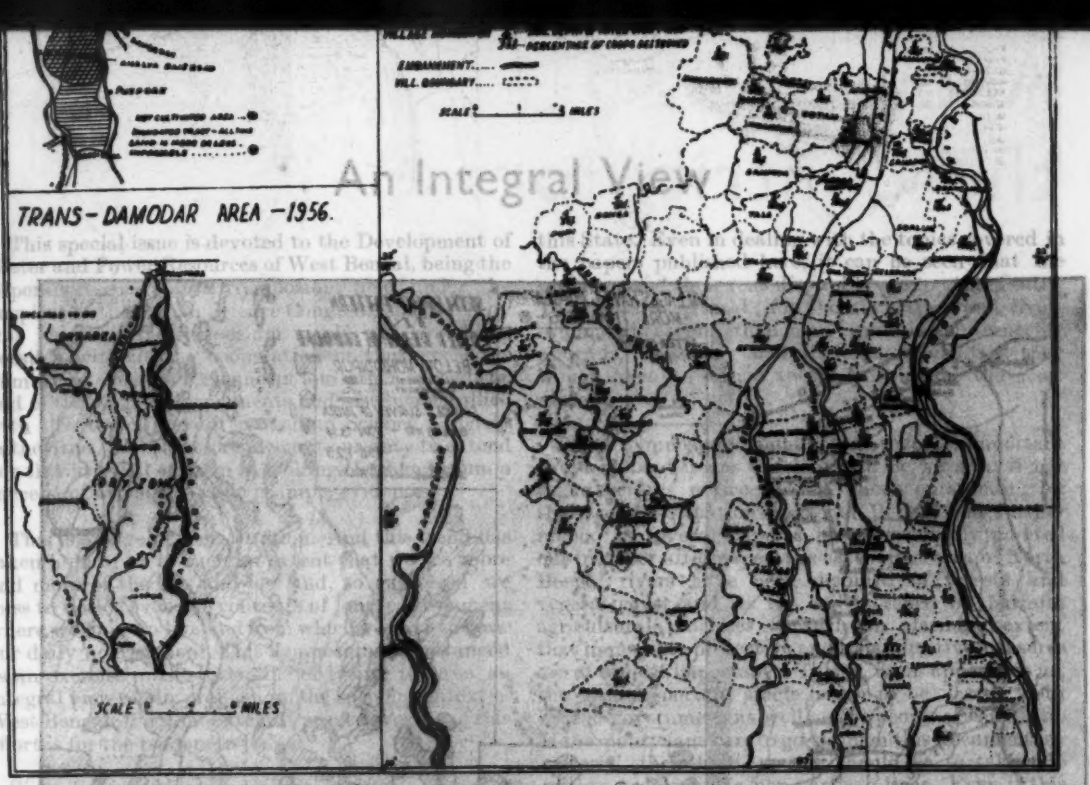


FIG. 60

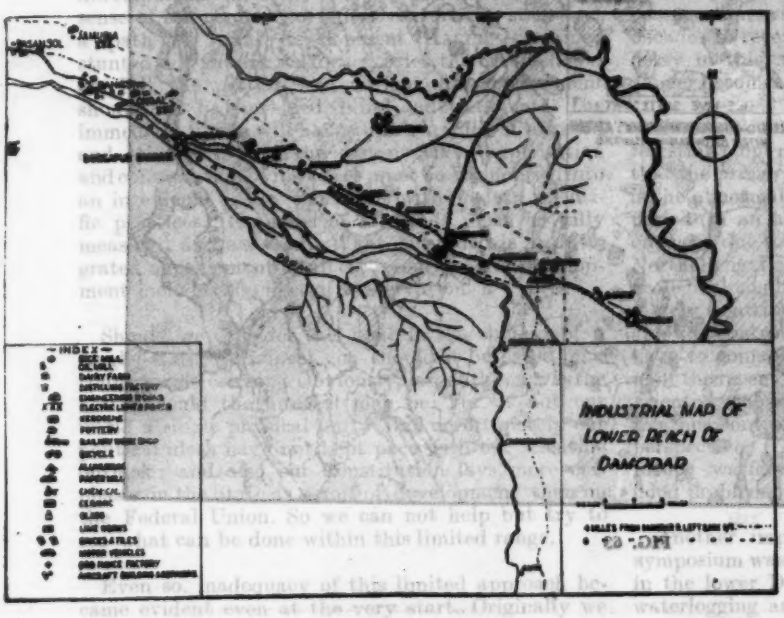


FIG. 61

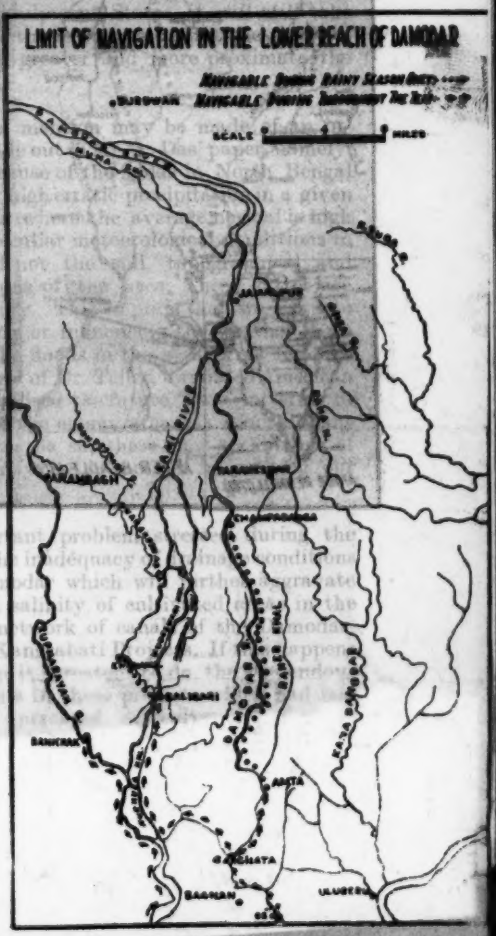


FIG. 62

FIG. 63

An Integral View

This special issue is devoted to the Development of Water and Power Resources of West Bengal, being the papers presented at a Symposium held under the auspices of the Indian Science Congress, sponsored by this journal. The symposium would not have been possible without the cooperation of the very large number of scientists, engineers and other specialists, and of the various departments and institutions allied with this topic, and of the Indian Science Congress authorities. We, therefore, deem it our duty to extend our thanks to all of them in making the symposium a success, of which this issue is ample evidence.

This is an age of specialisation. And this trend has taken hold of us to such an extent that we see more and more of the less and less and, so engrossed, we miss to notice even the contours of our environment where we have to live and from which we have to draw our daily nourishment. This symposium was arranged as an exercise in the discipline of trying to have an integral view of our problem in the specific context of West Bengal. To what extent it proved worthy of this effort is for the readers to judge.

Since independence India has entered a phase of development. Ensured of political stability and a sense of self-confidence, it has ventured to strike out a path of rapid development. Having remained stunted and suppressed for centuries, this is as it should be. But the pattern and outlook for development should not be one-sided, blind and passionate. The immediate future will have to be carefully integrated and telescoped into the distant one ; exploitation and conservation of resources must be harmonised into an intelligent policy consistent with modern scientific practices. Resources of all kinds must be fully measured and assessed. What is needed is an integrated development of all the resources. And development includes the idea of conservation.

Should we consider this issue in the context of a single state (province), or should it be based on a countrywide canvas ? Obviously, larger the canvas the better would the integral plan be. For, is not our world a single physical unit ? But unfortunately our political ideas have not kept pace with our scientific outlook ; and also our Constitution lays more emphasis on the State as a unit of development than on the Federal Union. So we can not help but try to see what can be done within this limited range.

Even so, inadequacy of this limited approach became evident even at the very start. Originally we had included in our list of subjects for consideration such problems as the Inland Water Transport, Ganga Barrage, Calcutta Port, and collaboration with other adjacent States. These are very vital questions for this small State of West Bengal. But we had to drop them because this would have raised delicate and controversial problems affecting many others besides this State. Even in dealing with the topics covered in the papers published here, it can be seen that the problems and their remedies spill over to other States. This is quite natural ; for the mountains and rivers originated earlier than man and his internecine quarrels, and they had little knowledge that they would have to adjust to the politics of the *homo sapiens*.

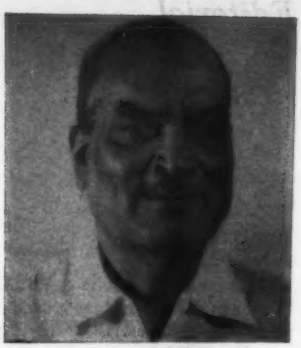
This Symposium highlighted several important problems and issues which it will be harmful if not taken serious notice of. The most outstanding of these is the situation of North Bengal and further north. As several experts have repeatedly pointed out in paper after paper, the catchment area of North Bengal rivers have been denuded of forests and vegetal cover and its top soil loosened by harmful agricultural practices to such an alarming extent that immediate protective and rehabilitative measures are of utmost importance. This is, as it appears to us, the most important single lesson to be learnt both by the government as well as the people of the State. If the politicians care to go through this documentary material, their first reaction should be to take this mighty problem as a non-partisan issue. Even if this be done, and action taken on a large enough scale, in co-operation with adjacent States, it will still take decades to recever the lost ground. But the more we delay in this, the greater and more proximate the danger becomes.

Here, of course, mention may be made of an interesting point made out in Mr. A. Das' paper, namely, that the *primary* cause of the floods in North Bengal is the abnormally high erratic precipitation in a given period (in an area where the average normal is high enough), due to peculiar meteorological conditions in North Bengal and not the soil, topographical and geological conditions of the area. These latter are merely contributory. This implies that we have to aim at controlling or influencing the weather if we have to control the floods in the area. This reminds us of the recent view of Dr. Teller, a reputed American scientist, who visualised the future 'wars' in terms of weather control of the enemy areas as a not-distant perspective. If this be so, these new techniques of future warfare may be harnessed in meeting our flood problems.

Another important problem stressed during the symposium was the inadequacy of drainage conditions in the lower Damodar which will further aggravate waterlogging and salinity of cultivated areas in the context of the network of canals of the Damodar, Mayurakshi and Kangsabati Projects. If this happens on a large scale, as it threatens to do, the stupendous capital investments in these projects which had laid great hopes on increased agricultural production would prove partially useless. Experts are also very

[*Continued on page* 122

About the Contributors



Dr. B. C. ROY
President, Indian Science Congress

Mr. AJOY KUMAR MUKHERJIwas bron 1901 at Tamluk, Distt. Midnapur. At a call from Mahatma Gandhi and Congress, non-co-operated just on the eve of appearing for B. Sc. Examination from Presidency College, Calcutta in 1920-21. Was the Secretary of Tamluk Sub-Divisional Congress Committee, District Midnapur for over 30 years. Secretary Midnapur District Congress Committee which post he resigned after being chosen as Minister for Irrigation and Waterways Department. Treasurer of West Bengal Provincial Congress Committee and member of All India Congress Committee. Was a Sarbadhinayak (Head) of Jatiya Sarkar (National Government) run in Tamluk Sub-Division of Midnapur District during August 1942 Movement. Had four terms of imprisonment which together ran upto twelve years. Minister, Irrigation and Waterways (1952 & 1957).

Dr. G. P. CHATTERJEE graduated with Honours from the Presidency College, Calcutta, in 1929, and then graduated from the Technical Institute, Jamshedpur, in 1931. Worked at the Tata Iron & Steel Co., and then joined the Bengal Engineering College, passed final B. Met. Examination in 1943. He worked at the Tata Iron and Steel Co. for more than 17 years. Later he went to the United States of America and obtained two Doctorates—one in Metallurgy (1948) and the other in Physics (1949)—from the University of Pittsburgh, U. S. A. He joined the Bengal Engineering College as Assistant Professor of Metallurgy in 1949 and became the Professor and Head of the Department of Metallurgy and Chemistry in 1952. Published more than seventy research papers in different journals of this country and abroad. He is a Member of the Metals Research Committee, Government of India, Member of the Scientific Advisory Committee of the National Metallurgical Laboratory, Life Member of the Indian Association for the Cultivation of Science, a member of the Institution of Engineers (India), Indian Institute of Metals, American Society of Metals, Life Member of the Mining, Geological and Metallurgical Institute (India), and many other learned and professional societies. He is also a past President of the Engineering and Metallurgy Section of the Indian Science Congress Association. He has recently gone on deputation to the U. S. A. as Officer-in-Charge of Indian Steel Training and Educational Programme.

Mr. P. R. AHUJA graduated in Civil Engineering from London University and also secured the A. C. G. I. in 1934. In 1950 he he was elected as a full Member of the Institution of Engineers (India). Ahuja has had varied experience with structural firms in England and India, and later with the Punjab Irrigation Department. During the War he was with the Army. Associated with the Central Board of Irrigation & Power and the Central Water and Power Commission from 1947. Represented India at the International Executive Council meeting of the International Commission of Large Dams and the World Power Conference in Belgium in 1949. In 1951 he took an active part in the International Commission on Large Dams, World Power Conference, International Commission on Irrigation and Drainage and the Engineering exhibition held in New Delhi.

In September, 1954 he attended the Working Group of Experts on Hydrological Terminology and Deficiencies in Hydrological Data for the ECAFE region. Again in September, 1956 he attended the Flood Symposium held at Djion (France). Delivering lectures both at the Refresher and Water Resources Development Centre at Roorkee University on hydrological aspects. Also delivered lectures at the FAO Development Centre on Watershed Management in Hazaribagh. At present Director, Hydrology and Statistics CW & PC.

Mr. E. A. R. BANERJI was recently Joint Director of Agriculture, West Bengal. He took his M. Sc. degree from the University of Calcutta and subsequently the post-graduate Diploma in Agricultural Science from the University of Cambridge, U. K. Before partition Banerji was the Fibre Expert of undivided Bengal. After partition he was the Economic Botanist to the Government of West Bengal and from 1949 he has been working as the Joint Director of Agriculture, West Bengal. Visited Europe, Sikkim and Cambodia under F. A. O. Fellowship, etc. At present with the Govt. of India in the Ministry of Food and Agriculture.

Mr. A. K. BHAUMIK is a Science Graduate from the Calcutta University in 1929, and B. Sc. in Engineering from the London University. Worked for about 2½ years with M/s. Metropolitan Vickers Ltd., London and on his return for about 2 years in the Railways, 3-4 years wit M/s. British Insulated Callender's Cables Ltd., Calcutta, for construction and design of High Tension Transmission Lines and Substations. Five years Resident Engineer and Manager of a group of Electricity Undertakings in U. P. and subsequently another five years as Sr. Project Officer, Central Water and Power Commission, Govt. of India. His major work in the CW & PC has been assessment of load potentialities in various River Valley Projects in India, such as Damodar Valley, Chambal, etc. Now for the last seven years he is Chief Electrical Engineer and Electrical Adviser to the Govt. of W. Bengal. Since 1955, also Electrical Engineer Member of the West Bengal State

Mr. AJOY KUMAR MUKHERJI
Chief Guest

Dr. G. P. CHATTERJEE
Chairman

Dr. N. K. BOSE

Dr. A. LAHIRI

Mr. A. K. BHAUMICK

Electricity Board. A full member of the Institution of Electrical Engineers, London, and the Institution of Engineers, India.

Dr. N. K. BOSE, born in 1896, has been founder-Director of the River Research Institute, West Bengal and founder Hydraulic Model Station, Damodar Valley Corporation. He is Advisor to the River Research Station, Assam Government, Fellow, National Institute of Sciences, Companion Member, Institute of Engineers, India, Consultant, Bureau of Flood Control, ECAFE. He was member of Kosi Ad-Hoc Committee. He is member of several Committees, such as the Hooghly Expert Committee, Greater Calcutta Drainage Committee, Calcutta Corporation Special Committee, Land and Water Utilisation Board, Government of West Bengal. He has been the Chairman of Standing Advisory Committee on Water Requirement of Crops, Government of West Bengal, Chairman, Hydro-Meteorological Co-ordination Committee, Government of West Bengal; Member-Secretary, Damodar Flood Enquiry Committee, (1944-45); Member-Secretary, West Bengal Flood Enquiry Committee, (1956-57); He is also Readership Lecturer, Calcutta University on "Present-day Irrigation Practice"; Ripon Professor, Indian Association for the Cultivation of Science; Acharyya Jagadish Chandra Bose Memorial Lecturer. Joint Author with Mr. A. N. Khosla of the Central Board of Irrigation Publication No. 12 "Design of Weirs on Permeable Foundation".

Dr. U. K. BOSE passed M. Sc. in 1935 and received Ph. D. in 1941 from the Lucknow University. The external examiners Prof A. H. Compton, N. L. and Prof. J. J. Frank, N. L., spoke very highly about the thesis. Joined the Indian Meteorological Service in 1942 and was on deputation to the I. A. F. (A & S. D. Branch) during the II World War from 1953 to 1947. At present posted in the office of the Director General of Observatories, New Delhi.

K.C. CHAKRAVORTY passed M.Sc. in Physics from University College of Science, Calcutta in 1927. Joined Indian Meteorological Department in April 1929. Held charge of various items of technical work including weather forecasting and storm warning in the department in different capacities. Wrote a number of scientific papers on the subjects of Meteorology and Seismology which were published in different journals. At present holding charge of the Forecasting Office at Alipore in the capacity of a meteorologist.

R.B. CHAKRAVARTY is Superintending Engineer in the Irrigation and Waterways Department of the West Bengal Government. At present in charge of the Kangsabati Project. He acquitted himself very creditably in the construction of the Canada Dam in the Mayurakshi Project.

Mr. A. DAS was a Senior Meteorologist in the Meteorological Department till his retirement in early 1957. He was in charge of the Damodar Valley Meteorological Unit.

Dr. M. DATTA was educated at the College of Science and Technology of Calcutta University from where he gained first class in Applied Physics in 1927. In 1933 he went for higher studies in the Municipal College of Technology, Manchester University and secured M. Sc. Tech. He joined M/s. Metropolitan Vickers Elect. Co. Ltd. and M/s. B. I. Cables before he was selected by the Govt. of India for commercial training in the Electric Supply Industry in England. On return he took charge of the Commercial Wing of the Electricity Development Directorate. In 1950 he was awarded the degree of Ph.D. by the University of Edinburgh and also became Member of the Institute of Electrical Engineers, London, in 1951. Since the formation of the West Bengal State Electricity Board, Dr. Datta held the office of the Secretary in addition to his own as Superintending Engineer till 1956 when he was sent abroad by the State Electricity Board for obtaining experience in Hydro Power Engineering.

Dr. Datta is at present entrusted with the implementation of the Jaldhaka Hydro-electric Project and Central Testing Laboratory in addition to his duties on commercial side.

Mr. G.N. DUTT obtained his postgraduate degree in Geology from the University of Calcutta in 1941 and joined the Geological Survey of India in 1943. He has been carrying out extensive geological mapping in Bihar, Rajasthan and various parts of the Himalayas from the Kashmir State to the frontiers of Burma in Assam,

Mr. K. B. RAY

Mr. V. S. RAO

Dr. S. K. MUKHERJI

Mr. A. C. GUPTA

Dr. M. DATTA

Mr. P. R. AHUJA

including the states of Nepal and Sikkim. While in Nepal he was deputed by the Government of India to join the British Everest Reconnaissance in 1951 as a geologist. Having worked four years in Sikkim he was attached to the Soil Conservation and Flood Control Organisation of the Government of West Bengal during 1956. Mr. Dutt left India in November, 1956 for England for research work in Geology as a Nuffield Foundation Fellow and again in November 1957 he went to West Germany for a three months' study tour as a guest of the West German Government.

Mr. A. C. GUPTA graduated in science with honours from the Presidency College, Calcutta in 1923, and later graduated from the University of Oxford in 1926. Appointed to the Indian Forest Service in 1926. Worked in the forests of England, France and Czechoslovakia. Served as a Divisional Forest Officer in Chittagong, Chittagong Hill Tracts, Dacca-Mymensing and the Sunderbans. Early in 1956 deputed to the Irrigation and Waterways Directorate for a detailed survey of the upper catchment of the Teesta river in Sikkim aimed at checking soil erosion and the moderation of flood. The first major landslip in the Darjeeling district to be effectively stabilised was done by him in 1939-41 as the Divisional Forest Officer of Kalimpong.

Mr. S. GUPTA is Superintending Engineer in the Irrigation and Waterways Department of the Govt. of West Bengal, in charge of the Mayurakshi Canals. He is a very senior engineer having been associated with D. V. C. for some time.

Mr. A. D. KHANNA is graduate of the Punjab University and qualified as Civil Engineer from the Thomason Engineering College, Roorkee in 1925. Deputy Director in the Hydrology and Statistics Directorate of the C. W. & P. C. Has been engaged on multifarious hydrologic studies in connection with river valley projects.

Dr. LAHIRI, Director, Central Fuel Research Institute, Jealgora, had his early collegiate eductation at the Presidency College, Calcutta. After a brilliant academic record, he proceeded to U.K. on Foreign Scholarship of the Calcutta University. In U. K. he obtained Ph. D. (in 1940) and his doctorate thesis was awarded the Judd Memorial prize for the best thesis of the year in the subjects of geology and geochemistry. Later, Dr. Lahiri specialized in chemical engineering and fuel technology and conducted original researches on oil shales. After a brief period of appointment as Research Assistant to Prof. Egerton, F. R. S. he took charge of the Fuels and Oil Laboratory of the Royal Aircraft Establishment, Farnborough, England.

In 1945 he returned to India as Assistant Director (Planning) of the Fuel Research Institute and Officer-in-Charge of Coal Survey Stations of the F. R. I. He became its Deputy Director in 1953 and Director in April, 1954.

Dr. Lahiri is closely associated with the growth and development of the Fuel Research Institute and also is an active member of a large number of technical committees of the Government of India and State Governments. His share in the planning of practically all the fuel-based industries of India since Independence is considerable. During his several trips abroad he has made close study of the working of industries based on coal and its byproducts His research publications number nearly 200.

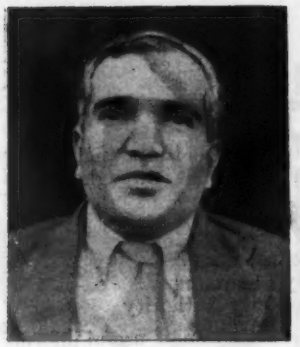
Dr. Lahiri is a Member of the Institute of Fuel, a Member of the Institute of Petroleum, an Associate of the Royal Institute of Chemistry, a Fellow of the National Academy of Sciences, India, and a Member of the British Rheologists Club. He is the Secretary of the Fuel Research Committee of the Board of Scientific and Industrial Research, Secretary of the Regional Coal Survey Committee of the Fuel Research Institute, and Secretary of the India Section of the Institute of Fuel (U. K.).

Mr. D. MOOKERJEE obtained the Degree of Bachelor of Engineering (1st Class) in 1935 from Calcutta University and post graduate training in the East Indian Railway Administration. Worked for the firm of architects M/s. Ballardie Thompson & Matheas F.F.R.I.B.A. and then joined the Irrigation and Waterways Dept. in 1938. and was employed in Contour Survey of Central and North Bengal. Worked as

Mr. A. D. KHANNA

Mr. E. A. R. BANERJI

Mr. D. MOOKERJEA



Mr. K. N. RAO

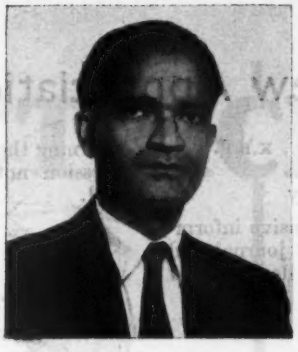
Dy. Director of the River Research Institute in 1949-50. Then drafted as incharge of designs and subsequently to construction in Mayurakshi Project. Joined the DVC in January, 1953, and except for a short period of 6 months in 1956 when his services were requisitioned by the CW & PC, he has been directly responsible for the designs and execution of the Durgapur Barrage and Canals Systems.

Dr. S. K. MUKHERJI graduated from Lucknow University and obtained Masters Degree from Allahabad University securing first position in science. Was an Empress Victoria Scholar and obtained Doctorate degree from Allahabad University. Joined the Department of Agriculture of Uttar Pradesh and worked in Animal Nutrition, Sugarcane soil survey, Agricultural Chemistry and taught Post Graduate classes of Agra University. Joined Agriculture Department of West Bengal as Agricultural Chemist. Published more than forty scientific papers in different scientific journals of India and abroad.

Mr. H. R. PRAMANIK passed M.Sc. in Applied Mathematics with a First Class from the Calcutta University in 1939. Obtained degree of M.S. in Hydraulic Engineering from the State University of Iowa, U.S.A. in 1950. Worked in the River Research Institute as Research Officer for 5 years and as Deputy Director for the last 6 years.

Mr. K. N. RAO, stood first in the B.Sc. (Hons) and M.Sc, examinations of the University of Mysore in Mathematics. Worked as a Research Student for about a year in Theoretical Physics and later as Research Assistant under Sir C.V. Raman, F.R.S., N.L., at the Indian Institute of Science. Joined the Indian Meteorological Department in 1939 and became Director in June, 1957. Was in-charge of the Statistical and Climatological and Observatory Sections in the Office of the Deputy Director General of Observatories (Climatology and Geophysics) for over a decade. Has also worked as in-charge of Forecasting Office. Has published over 20 papers.

Mr. V. S. RAO with Chemistry graduate degree of the Madras University, was selected for the Indian Forest Service in 1928.



Mr. G. N. DUTT

After a course at Dehra Dun was allotted to Bengal in 1930. Worked in Jalpaiguri, Chittagong, Chittagong Hill Tracts, Khulna, Dacca-Mymensing, Kurseong and Midnapore. Was sent for 6 months on an F.A.O. sponsored Soil Conservation Study Tour in 1953 in U.S.A. and Europe. Conservator General of Forests, West Bengal from September 1956. Is member of the Darjeeling Landslide Enquiry Committee, North Bengal Flood Enquiry Committee, West Bengal Flood Control Board, and West Bengal (Central, Southern and Western Districts) Flood Enquiry Committee.

Mr. K. B. RAY was a retired Superintending Engineer in the pre-Independence East Bengal Railways and was associated in the work of training of rivers in East and North Bengal, Assam and North Bihar. He took keen interest in the hydraulic problems of the country even after retirement. Unfortunately he could not attend the Symposium and soon after death overtook him.

Mr. P. B. ROY is a senior officer in the W. Bengal River Research Institute.

Mr. P. R. ROY CHOUDHURY graduated in Electrical Engineering from the College of Engineering & Technology (Jadavpur College) in 1945. Joined the Commercial Division of the Central Water and Power Commission (Power Wing) and in 1952 the Commercial Engineers' Department of the DVC at Calcutta and still continuing there.

Mr. SATYAKAM SEN took his M.A. degree in Geography from the Calcutta University and did research work with the River Research Institute of W. Bengal as a special Research Student. He is at present with the National Atlas Division of the Govt. of India.

Mr. G. SINHA is M.A. of Calcutta University in Applied Mathematics. He was Ghosh Research Scholar in the University College of Science, Calcutta. Formerly, Statistical Officer, Health Department, Calcutta Corporation, he became Research Officer, River Research Institute, West Bengal, in charge of Statistics Section in 1946. He was sent to Holland by the West Bengal Govt. in 1956 for training in mathematical methods of tidal computation.

Dr. U. K. BOSE

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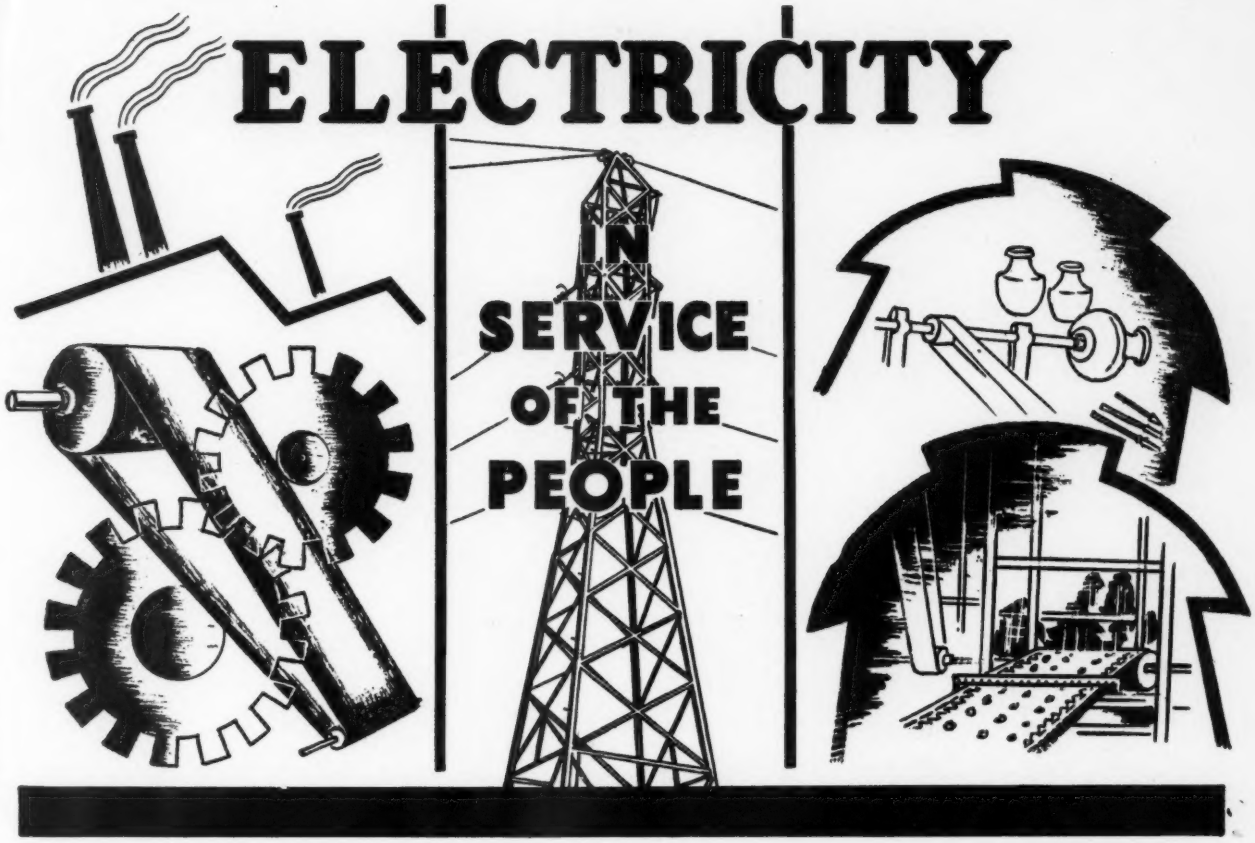

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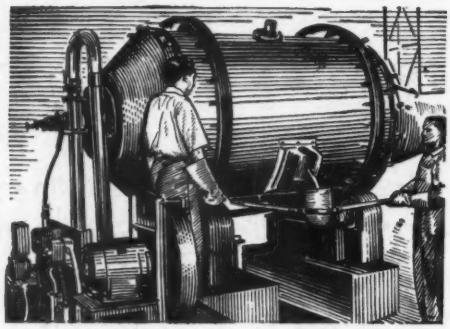

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